STREAM POLLUTION IN NEW YORK STATE

By HENRY B. WARD, Ph. D.
Professor of Zoology in the University of Illinois

STATE OF NEW YORK
CONSERVATION COMMISSION
ALBANY
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A Preliminary Investigation of the Problem from the Standpoint of the Biologist

Made in July and August, 1918

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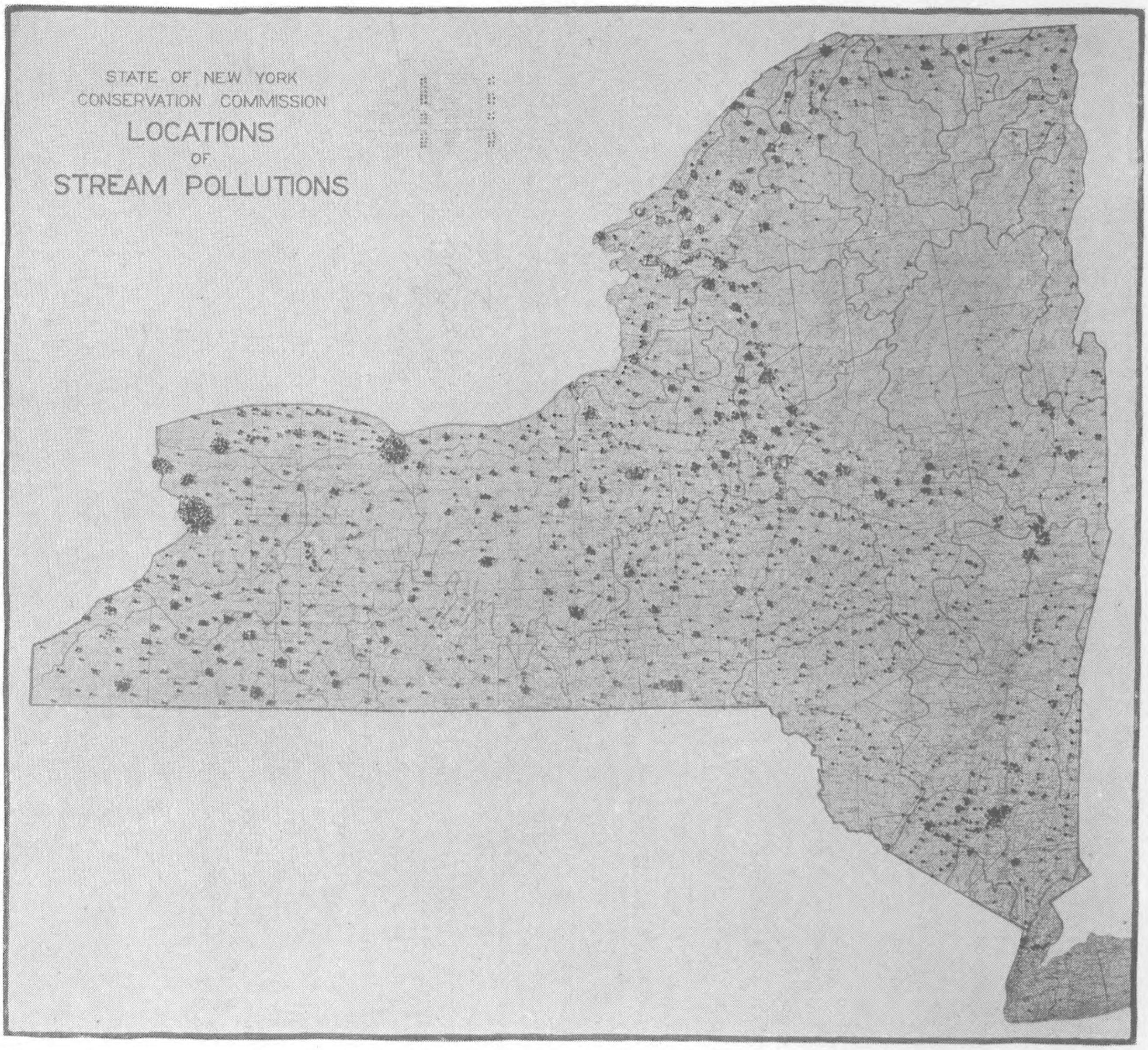

MAP OF STREAM POLLUTIONS IN NEW YORK STATE

On this map, industrial establishments that are potential polluters of streams are indicated by pins of different colors, each class of industry being assigned a distinctive color. The heavy irregular lines indicate the boundaries of river systems. The map is thus a visual representation of conditions upon every watershed, and of the extent of pollution over the entire state.

STREAM POLLUTION IN NEW YORK STATE

FOREWORD

In June, 1918, I was honored by an invitation from the Conservation Commission to spend the summer in studying the problem of stream pollution in New York state. In the original letter Commissioner George D. Pratt wrote, " The state laws prohibit the discharge of factory waste, chemicals, etc., in quantities sufficient to kill fish. The law has been inadequate for the reason that it is difficult to prove that the discharge is the cause of the mortality." In replying I called attention to the fact that the question has various aspects, the legal, the chemical, and the biological and indicated my own lack of fitness to consider the problem from either the first or the second viewpoint; but indicated that if the question was felt to call for biological investigation, I was both ready and interested to take it up. I felt it necessary to emphasize that fact at the outset because I was conscious that as a rule the biological side of the problem had been greatly neglected if not entirely overlooked. Personally, I was inclined to feel that this aspect was important and offered little appreciated opportunities for aiding in the solution of the questions involved; yet I knew there were those who did not regard it as sufficiently significant to demand consideration early in any such investigation. I found that the Conservation Commission was already far advanced in the study of other phases of the problem of stream pollution and welcomed an examination and development of this phase which had not heretofore received special attention at their hands.

This statement must be made at the outset in order to show clearly from what point of view the subject is attacked in the discussion that follows. I do not fail to appreciate the importance and even the essential character of other considerations even though they are not discussed in subsequent pages of this report.

The time devoted to the investigation was only about two months and this is evidently inadequate even for a reconnoissance in a field

so large and on a problem so involved. Whatever success may have been attained in securing an outline of the situation and formulating the plan submitted herewith is due in first instance to the cordial cooperation extended by the staff of the Commission. Everyone with whom I came in contact manifested a personal interest in the work and devoted time and energy enthusiastically to assisting in every possible way.

IMPORTANCE OF THE PROBLEM OF STREAM POLLUTION

The problem of stream pollution is undoubtedly one of the most important at present before the country. A prominent member of the United States Food Administration who was concerned with the question of fish foods and particularly the means for increasing the amount and facilitating the distribution thereof, in order to add to the general food supply of the country during the war, has stated that more than 60 per cent of the suggestions sent in for his assistance from all the parts of the country urged on his attention some aspect of the question of stream pollution and its correction because in the solution of this problem lay everywhere the greatest possibilities for the improvement of fisheries and the increase in fish food.

Evidently the question presents itself in its most serious aspects in the oldest parts of the country and in those regions which possess the largest population and the greatest manufacturing interests. As might be expected, New York state, by virtue of all of these features, is one in which stream pollution has become marked and has exercised a powerful and unfortunate influence on the streams and their fisheries. Of course even within the limits of the Empire State, however, conditions vary quite as widely as they do between the most extreme parts of the country. In the heart of the Adirondack Mountains and amid the protected surroundings of the Forest Preserve stream pollution is so little significant that a game protector in such a place could report in perfectly good faith, "I never heard of any instance in my territory." But along the valleys manufacturing interests have been concentrated until the accumulated wastes of city and factory make of the splendid rivers of the state sources of danger rather than of pleasure and profit. For years our greatest city has been justly protesting against the polluted condition of the magnificent river that has been in the past a source of pride not only to that city but to the state and the nation. And it is not merely a question of sentiment, for those who have studied the problems of the fisheries and have seen something of the present condition of the Hudson river will not hesitate to maintain that the commercial value of the stream has been very greatly reduced by the conditions that exist in it at the present time.

It is wise to note here the situation in other countries, lest some

one should be tempted to suggest that these conditions are the unavoidable results of increase in population and in manufacturing, that the old time natural conditions could only be maintained when men were scattered and manufacturing activities simple in character and limited in extent, and hence that they have disappeared forever — a loss which one should regret, yet must acknowledge to be inseparably connected with the development of a more effective social organization. In Europe the population is generally much denser than here, and there are many regions where manufacturing has been carried on far longer and more intensively than here. Those countries have had to meet the same problems in the disposal of wastes which confront us here, and often in more acute form. The careless, unsanitary centuries of the past had left an accumulated burden of wastes in city and town and along river and lake that made the solution of the question more difficult by far than it is here. Prejudice and conservatism have been obstacles there of real moment, and yet in numbers of such places the situation has been well handled. One should not claim that all problems have been solved or all waters restored to proper condition, but fishing is better in streams of the Old World than in similar regions in New York state, and the rivers of Europe are less polluted than corresponding streams here. This is the result of active public interest and definite work on the problem. The work which has been done there has demonstrated that satisfactory results can be achieved and in many cases has furnished the specific methods for handling our own problems. If our indifference and inattention can be transformed into active concern, then even greater results can be attained here.

MULTIPLICITY AND SIGNIFICANCE OF AQUATIC ORGANISMS

Number and Variety

The life of our waters is both varied and abundant. It differs from the life of the land chiefly in that the most conspicuous and largest types of both animals and plants are lacking, but the number and variety of the smaller forms and of the microscopic species is abundant beyond all ordinary conception. One has only to glance over the pages of such a work as *The Life of Inland Waters* by Professor James G. Needham of Cornell and his colleague, Mr. J. T. Lloyd, to find a wealth of information and abundant illustrations of this life. In it one may become familiar with the various types of aquatic environment, the various aquatic organisms, both plant and animal forms, and with their adjustment to conditions of aquatic life. One finds that they are organized into definite aquatic societies which depend upon different conditions for their existence, and accordingly occur in different places. More intensive treatment of some of the same factors is found in the appropriate chapters of a book by Professor V. E. Shelford entitled *Animal Communities in Temperate America;* and, finally, if there is need to emphasize the abundance and variety of such organisms, evidence will be obtained from a recent work entitled *Fresh-Water Biology* which I have published with the cooperation of a series of specialists on various groups. It may indicate the wealth of the forms found in North American fresh water to say that over 1100 pages are required to present a summary of the topic and the 1547 illustrations used do not show even all the important genera as only a few forms are figured under fishes, insects and plants. Under natural conditions, the aquatic species are varied and beautiful in form and extraordinarily abundant in numbers.

Relation to Purity of Water

Observation of any individual water body with reference to the character of the organisms in it and the abundance of these smaller types of life yields readily incontrovertible evidence with reference to the purity of its water. For the most part these minute organisms are confined to a limited area or, if distributed more widely, are

dependent upon the action of the current for transport. Furthermore, while the naturalist may at times collect a few specimens for study, the abundance of the forms is, generally speaking, so great that the effect of such collecting cannot be detected immediately after it has been done, and in most cases the only way in which this fauna and flora can be eliminated is through the influence of unfavorable conditions in the environment. If some chance fisherman has hunted certain kinds of insect larvae for bait, such as dobson and helgramites, there are still to be found normally scores and hundreds of other sorts, and their absence is clear evidence of some general influence of an unfavorable character. Furthermore, the argument does not rest upon any particular species or even upon any single group and takes into account both animals and plants, the kinds that grow fast to the stones on the bottom, those that frequent shallows, or occur only in the deeper places, the varieties that float in the water as well as those that burrow in the bed of the stream. Finally, we know in considerable measure the relation of individual organisms to water conditions. We recognize that certain species are rare and others abundant, that a given form occurs only in pure waters and other types are seen only in polluted streams. We recognize also types that are intermediate and so by the gradual appearance and disappearance of series of organisms we can trace directly the transition from an area of pure water with its characteristic organisms to a polluted region with entirely different types of life, or in the extreme instance, without any living organisms whatever

The estimate which one places on biological conditions of the land surface in any given region is based, not upon a single item but upon the general appearance of the area, and takes into account all of the features. We have come in daily contact with these so long that we take in complex factors at a glance and pass judgment almost instantaneously with regard to the condition of the lawn, or field, or garden tract. Now, the same test may be applied without difficulty to water bodies, though it is, for reasons already mentioned, not quite so easy to see the condition as in the case of a land area. We observe the sum total of appearances along the shore, in shallow waters, on bars in the stream, over the bed of the river or lake, and even in the open water itself. To be sure one is dealing here with factors which are not familiar to the ordinary individual, but they are well known to the students of such areas and data are easily accessible to the individual who desires to inform himself with regard to the situation.

NATURAL AND UNNATURAL CONDITIONS OF AQUATIC EXISTENCE

Essential Conditions

It is somewhat difficult for the mind to get a clear picture of conditions existing below the surface of the water. This is doubtless due to the fact that the light is largely reflected from that surface and does not display to us clearly the objects that lie beneath. The eye takes in at most limited areas, rather than the long stretches of bottom territory. It finds them very differently constituted from the surface of the dry land. We are inclined to consider the situation more complex and difficult to understand than it really is. In truth, the essentials of existence are the same in the water as on the land.

Each organism demands for its existence a certain food supply and it must have also a supply of oxygen available for respiration. A shortage of oxygen in the water has precisely the same effect upon fish that an insufficient supply of oxygen in the atmosphere has upon air breathing animals. All degrees of oxygen deficiencies may be observed in the water, as they are on the land in the atmosphere, and among the organisms of the water all grades of effect produced may be observed that are familiar to us among air breathing animals under similar atmospheric conditions. A shortage of oxygen either kills or stupefies the fish, or, it may be, drives them away from the abnormal environment to seek better conditions elsewhere.

Movements of Fish

A shortage of food is promptly met by the migration of fish from the region. Like other animals, they are quick to react toward an approaching shortage of food, and having considerable activity may desert a region entirely and move to some distant point without attracting the attention even of those who are watching the stream day by day. Fish also carry out natural movements of their own in response to the reproductive instinct and to modifications in the temperature of the water and to the amount of silt which it carries, or, in other words, to the variation of the stream with the changing seasons and periods of drought and rainfall. It is not easy to distinguish these migrations from those which are due to food shortage.

Furthermore, it is very evident that the absence of fish at a given point need not necessarily be explained by their movements at all. The readiest way to account for the situation is to furnish the ever-ready excuse that the stream has been over-fished. Knowing the situation superficially, the public is ready to accept this explanation, and there is no doubt that .t applies with full force to certain localities and to many kinds of fish. There are, however, some elements in the situation which are not always considered.

Effects of Catching Fish

In the first place, over-catching may reduce the supply of game and food fish, but it hardly has any such distinct effect upon the numerous other kinds, especially the intermediate and smaller species that are naturally abundant in most waters. Accordingly, if the reduction in the fish population were due to over-catching, one would expect to note the absence of those species which have been followed up by anglers and commercial fishermen, and at the same time to record the presence of the other sorts. In fact, our game and food fishes are almost exclusively large forms that spend their energies preying upon the smaller species, so that if the food fishes were eliminated, the smaller forms would meet with less competition and would become more abundant, and more conspicuous, also, for they would not be driven to sheltered places of concealment, but would have opportunities to range freely through the water, as they could not if the large types were preying upon them. Accordingly, the absence of the smaller types of fish is clearly indicative of the fact that in some respects at least the conditions of the environment are not satisfactory. It may be that the food supply is lacking, or that the chemical environment is prejudicial to health and normal existence, or finally that some factor has interfered with the carrying out of the reproductive functions.

Effects of Changed Environment

Every one of these conditions certainly obtains in individual cases. The reproductive period is perhaps the most vulnerable point in the life history of the fish and the one at which unfavorable conditions affect its numbers most rapidly and seriously. The erection of dams not provided with fishways interposes barriers beyond which the fish cannot go in its effort to reach head waters and small tributaries where many species spawn. These dams also establish a constant level for the stretch of the stream above the barrier. In this way

the shallows are eliminated and the beds of gravel may be covered too deeply for their utilization as spawning grounds by many fish. In case the dams are located close together, so that the water from one backs up close to the foot of the next above, this difficulty becomes very real. The construction of works for current regulation, such as lateral dikes, shutting off the shallow shore areas, also modifies the general character of the stream so radically as to put serious obstacles in the way of the spawning and development of many kinds of fish. Conditions of this sort may be seen between Albany and Troy and at other points along the Hudson. The elimination of shallow areas near the banks affects aquatic life more than might appear at first thought. These are the places where aquatic plants grow abundantly and where small aquatic animals are bred in multitudes. They afford spawning ground for certain of the fishes and furnish hiding places to the young fish of all sorts and to the smaller species. Finally they are the regions which hold out longest against the pollution of the water and in which suitable conditions of existence are found longer than in the open stream.

A little reflection will show clearly the extent to which natural conditions have been modified within recent years. The increase in population in New York state within fifty years is the first element in the change, but the influence of this is much less conspicuous than that of other factors. During the same period the character of the state has changed somewhat rapidly. The cities have grown greater; general farming is relatively a less conspicuous occupation of the citizens of the state. On the other hand the amount of manufacturing has increased enormously.

Increase of Chemical Wastes

Even this, however, does not bring out the most conspicuous element in the situation. The manufacturing of the present day is characterized in a conspicuous way by the chemical processes involved. These lead to the production of quantities of peculiar waste materials, and while the industrial wastes of the past were small in amount, relatively simple and stable in composition, those of the present are conspicuous for their volume and for the variety and changeful character of the materials produced. Where formerly the addition of such wastes resulted at most in the destruction of life in a small stream and in poisoning or polluting a relatively limited area surrounding the outlet, at the present time the frequent addition of new and powerful poisons in large quantities has

extended the areas in which life has been destroyed or highly modified until they extend for miles along the stream and involve entire rivers. In fact, in the most densely populated portions of the state and on the greater river systems, one source of pollution overlaps the one next lower down on the watershed to such an extent that the entire stream is seriously affected.

A new danger confronts us in considering modifications that have come over even the small village communities and towns in their relation to this problem. The sewage which they formerly turned out into a convenient stream was composed almost exclusively of organic wastes. It was subject to rapid transformation under natural conditions, and the stream flowing, as such streams do in most cases in this state, over a broken, stony or rocky bed, tended to accumulate oxygen and thereby to assist in the rapidity of the changes which led to the ultimate transformation of the domestic sewage into materials that could be utilized by living organisms.

Modification of Domestic Wastes

At the present time even in small villages it is not possible to find domestic sewage of an unmodified type. What is designated under that name is really a mixture containing often much trade waste. The existence of small factories, or at least machine shops with oil and gasoline waste that is turned into the sewer system, has transformed the original easily handled sewage material into that which resists the ordinary methods of self purification in flowing waters, and constitutes a lasting menace to the life that normally would be found in the streams.

It is an unfortunate fact that whatever may be the average yearly run off there has been in connection with these changes a distinct and considerable reduction at certain seasons in the volume of stream flow, so that even if sewage conditions had not been changed the amount of dilution would be much less at the present time than it was formerly. Thus the process has been unfavorably modified at both ends and at present the situation is changing conspicuously for the worse, so that it is necessary to look for some means of improving matters before the point is reached where all the life of our streams will have been destroyed.

Canalization Lessens Purification

In some regions another factor has been an important element in increasing the difficulties of the situation, and that is the modification of the stream itself through canalization. Water flowing over

a stony or rocky bottom with falls or rapids from point to point to mix it with the air will take on oxygen very rapidly. Once, however, let the current be stopped and the water accumulated in deep, slow flowing masses, the process of purification is almost entirely inhibited so that it proceeds very slowly indeed. This is exactly the condition which has arisen as the streams have been more and more perfectly utilized for water power. The erection of a dam below a series of rapids or ripples, impounding the water to a considerable depth and backing it up to a point which in the ultimate development of the stream will represent approximately the base of the dam next higher up, makes of a natural water course with its rapidly flowing current only a series of ponds in which the movement is almost imperceptible. Wastes delivered into the stream when the latter has reached this condition of stability will be precipitated to form a layer on the bottom, the thickness of which is regulated by the amount, and the change in which is reduced nearly to zero. Where in the original condition the stream might have endured the contamination and have been able to effect self purification within a reasonable distance, the new conditions are entirely unfavorable for changes and under them the stream is transformed into what, in these conditions, is simply a series of septic tanks. In these, the life characteristic of pure waters is entirely eliminated and the only organisms which can survive are those of putrefaction.

Canalization is a necessary feature of our modern industrial development, but pollution, the evil effects of which are seriously augumented by canalization, has no such argument in its favor. Canalization thus provides a new reason for the elimination of stream contamination.

Influence of Pollution on Aquatic Life

Let us consider more carefully the effect of stream pollution upon fish life. At another place in the discussion I have taken up the question as to whether the absence of fish from streams is due to pollution or to other causes. In those instances in which pollution is both recognized and admitted, there certainly must have been considerable influence exerted upon the availability of those waters as areas for the existence and propagation of fish.

If the substances which are discharged into the water are directly poisonous to fish and are poured out in such quantities that even the volume of the stream does not dilute them beyond the point at which the poison is fatal, the entire fish population will be killed or driven

away and the area coming under the influence of this waste become thereby barren of fish life. Plenty of evidence can be given to prove that this occurs frequently, on streams of moderate or small size. While such areas are to be found, the absence of fish life is in fact not the most serious characteristic. In the adult condition the fish are relatively large and as little susceptible to the effects of pollution as any organisms which inhabit the water. Even though they may be lacking from a given area, it 's often the case that they have been driven away by adverse conditions, as well as directly destroyed through poisonous substances. The net result of driving fish out of water that might be made productive is quite as bad as killing them in it.

Chemical substances which are of such a character as to destroy the life of the small organisms will eliminate from the territory those things on which directly or indirectly the fish feeds, and with the disappearance of its food the fish are forced to migrate or to starve. They are quick to respond to such influence, as is well known to fishermen, for by thoroughly baiting a given area with food, fish may be readily attracted into it and are, of course, also sought in those places that are the best feeding grounds. Conversely, an area barren of life is not a satisfactory place to go fishing. The absence of other forms of life is good evidence that the fish will not, in general, be found there. Evidently, then, agencies that tend to reduce a water area to a barren condition will be promptly instrumental in driving away the fish that naturally congregate in that territory.

Pollution and Fish Propagation

There is another way in which pollution of water very directly and seriously affects its fish population, and that is in the influence upon the propagation of the species. Fish deposit their eggs variously, but, in general, at selected points in the stream bottom, some species choosing one kind of environment and others selecting another. Fish seek for this purpose a clean area of bottom, or prepare it in definite fashion by brushing away the dirt from a limited space which serves as a nest. If the waters are highly polluted, the sediment which covers the bottom befouls the area and reduces the free oxygen to low terms. As a result, a satisfactory nest cannot be cleaned out, or, if it is, the adjacent decaying materials still affect the water so unfavorably that the eggs cannot live and the reproductive activities of the fish are seriously interfered

with. Migrating fish, like shad or salmon, that seek definite parts of the stream system for spawning, are compelled, in the absence of satisfactory locations, to spawn on polluted areas, and the eggs have little chance to develop properly. As the organism is exceedingly susceptible in this stage of its existence, conditions which could be endured by the adult fish will often prove fatal to the eggs. These conditions prevent the species from holding its own in the face of the demands upon the supply that are made by the fishermen.

Still another feature demands consideration in this connection. The state is breeding annually large quantities of young fish at considerable expense. It takes at the appropriate season the eggs of a given species, places them in a hatchery under proper conditions of development, and, after having protected them through the period of growth within the egg and perhaps, also, after having protected and fed them through the earlier stages of existence, it has a mass of fry or fingerlings to plant out for the rehabilitation of the stream. These stages are not so sensitive as the egg stage, for the fish with every period of time that elapses from the start of its development becomes more and more immune to the dangers of existence; yet even in these free-swimming young stages, the fry and fingerlings are much more delicate than the adult fish and will succumb to conditions that would merely drive away the adult rather than destroy them. It is hardly a profitable business for the state to raise at such a considerable expense quantities of young fish in order to plant them out in waters in which the chances of existence are unfavorable.

To summarize this phase of our study:

The pollution of the water, especially by industrial wastes, results first, in the death of the adults; or second, in driving them away from polluted areas. It makes the territory unfit for natural reproduction and destroys the eggs of the fish, thus interfering with the means for the preservation of the species. Finally, it brings to naught the efforts of the state for rehabilitating the supply of fish, since the young fish which are planted maintain a limited and precarious existence in polluted areas, if indeed they are not destroyed by the unfavorable environment.

GENERAL LOSSES BY STREAM POLLUTION

The value of the individual water body is not always apparent and the significance of the destruction wrought by eliminating the life from it frequently appears only after a careful analysis of the situation. It is not possible within the limits of this report to do more than indicate some phases of the argument on this question, but they will serve to suggest other particulars and to demonstrate clearly the need of careful study that the public may not suffer unrecognized losses of a serious character which it may be difficult to make good. In any case, it is expensive in time and money to restore a stream to its original condition. Individual examples of particular factors in the problem may be cited here.

Value of Small Streams

The small streams which empty into lakes or constitute the side branches of larger river systems are in a sense insignificant. Their area is trivial, the amount of water they carry is not large, and, from any standpoint, one might think the destruction of living conditions within them to be of little moment for the general welfare. But such places are, in the first instance, breeding grounds for the larger fish. At some period of the year, and often at several such for different species, fish migrate into the smaller and shallower waters, deposit their eggs and return to the larger environment. Unless one has studied the streams carefully, he may be entirely unacquainted with the fact of this relation, for while all know the movements of the larger fish, which, like shad or salmon, migrate in enormous schools to their spawning grounds, yet men do not recognize, generally, the movements of other species which go more irregularly or in smaller groups, and traverse shorter distances. Now, whatever renders the stream barren and incapable of supporting life eliminates it from functioning as a spawning ground, and it requires little reflection to see that the destruction of spawning areas limits or ultimately terminates the reproductive activities of the species and will be followed by the extermination of the fish. Indeed, there is no doubt that the marked reduction in the numbers of adult fish in many regions is directly traceable to the destruction of spawning grounds, or to the presence of conditions which if not fatal are very unfavorable to the young in the egg or fry stage when they are so susceptible to injurious influences.

Pollution in Small Streams

The effects of pollution in such a small stream are not, however, summed up completely by any means in the previous paragraph. The same contamination which renders the area unfit for reproductive purposes destroys the smaller organisms of the water. The insect larvae are killed, and the smaller crustaceans and the microscopic animals and plants suffer a similar fate. Now, these organisms multiply most rapidly in the shallower areas. They are produced constantly in enormous numbers in such places, and are carried on in part directly and in part through the medium of smaller fish to replenish the food supply of the other parts of the river system, and thus to furnish substances ultimately for the adult fish which immediately interest man. The effect of contaminating the smaller stream is seen in a diminution of the general food supply in the water system of which it is a part.

Effects on Larger Streams

These influences, however, are not confined to the smaller streams with which the discussion started. They affect equally the rivers and lakes with which these smaller streams connect. So long as the amount of pollution is small, the larger stream does not show the effect so quickly. It may be, indeed, that for a long time the amount of pollution affects the large stream merely within a limited area or only so much that the life in it does not find the opportunity for vigorous development, and the investigator examining the water has to record that various elements of the fauna and flora are scanty, that aquatic life is poorly developed or absent from some regions and confined to the more productive areas, or to portions in which the contribution from uncontaminated water in certain tributaries makes an area more favorable for the development of life. But, as the subsidiary streams become more and more affected, the main stream assumes an increasingly unfavorable condition, until the organisms of pure water are gradually but more or less completely replaced by those that characterize polluted waters. This replacement occurs first at the points of greatest pollution, such as near the discharge of an industrial waste or the inflow of a highly polluted side-stream. It extends down stream and over the general area of the larger water body, gradually eliminating all of the characteristics of the original river and substituting those of the open sewer.

Influence of Seasonal Changes

These conditions evidently vary with the seasons. When the natural flow in the stream is lowest, and the dilution of the water

less, then the greatest effect is noted, and a season of extremely low water is accompanied by a spread of the polluted area that often is conspicuous enough to attract the attention of the ordinary observer as well as of the trained naturalist. Instances illustrating all of these cases are on record in the office of the Conservation Commission, and are familiar to the public generally in statements concerning the conditions of streams at individual points as recorded by residents or inspectors of various kinds.

It is fortunate that ordinarily the water is highest at that time when one finds the largest migration of fish for spawning purposes, that is, in the months of spring and early summer; for high water results, first, in the maximum dilution of the wastes so that they do the least possible damage, and, in the second place, in washing out the accumulated material so that the bottom is relieved in part, at least, of the accumulated wastes that have been deposited through low water periods, and of the products of decay that have come from the destruction of life by the action of the wastes during the preceding seasons.

Shad in the Hudson

If it were not for this seasonal dilution, I imagine that the Hudson river would have suffered even more seriously than it has in the diminution of the shad run, for the number of shad that return annually to the stream to propagate themselves is directly related to the number of young fish that have been hatched in the river previously and have gone out to the ocean to feed and to grow to maturity. It is perfectly clear that the number of young shad migrating into ocean waters depends upon the success of the reproductive season in which they were hatched. It is only very imperfectly correlated with the number of eggs deposited, since the character of the bottom and of the water itself will determine pretty largely what per cent of the eggs hatch out successfully and what number of young shad-fry find food and other conditions favorable for existence so that they can complete their development and carry out successfully their movement into the ocean. The shad catch is a matter of large importance to the state and to the nation, and it clearly depends directly upon the condition of the stream. One may maintain confidently that its diminution in recent years is directly connected with the growing pollution of the river, although it would be impossible to say exactly to what degree it is affected thereby. Furthermore, one may prophesy with assurance that if pollution

increases as rapidly in the future as it has in the immediate past, the time is close at hand when the shad will be as great a rarity in the Hudson as the salmon is today in the Connecticut.

Salmon in Atlantic Rivers

It is worth while to recount briefly the history of the salmon in New England rivers as illustrated well by the record of the Connecticut river, from which, even though the cause is not the same, is indicated clearly what will happen to the shad of the Hudson if attention is not directed to the problem promptly and energetically enough to control the unfavorable conditions that are growing up and have gone so far at the present moment that the end of the story is in sight. In his discussion of the Atlantic salmon, David Starr Jordan writes as follows:

"The salmon was at one time very abundant in the Connecticut, and it probably occurred in the Housatonic and Hudson. * * * Many Connecticut people remember hearing their grandfathers say that when they went to the river to buy shad the fishermen used to stipulate that they should buy a specified number of salmon, also. But at the beginning of this century they began rapidly to diminish. Mitchill stated, in 1814, that in former days the supply to the New York market usually came from the Connecticut, but of late years from the Kennebec, covered with ice. Reverend David Dudley Field, writing in 1819, states that salmon had scarcely been seen in the Connecticut for 15 or 20 years. The circumstances of their extermination in the Connecticut are well known, and the same story, with names and dates changed, serves equally well for other rivers.

In 1798 a corporation, known as the 'Upper Locks and Canal Company' built a dam 16 feet high at Millers River, 100 miles from the mouth of the Connecticut. For 2 or 3 years fish were seen in great abundance, below the dam, and for perhaps 10 years they continued to appear, vainly striving to reach their spawning grounds; but soon the work of extermination was complete. When, in 1872, a solitary salmon made its appearance, the Saybrook fisherman did not know what it was."

This instance of the disappearance of a species from the aquatic fauna is definitely traceable to interference with the reproductive function. It concerns a form that had great economic value. Other cases can be cited that are equally clear and that bear directly upon the topic of this report. I shall use only one and it is almost as striking though the form concerned has only moderate economic worth.

Example of Illinois River

The effects of stream pollution on the aquatic fauna are well illustrated by the record of Forbes and Richardson (1913) of work done on the Illinois river. A simple group such as the mollusks, or particularly the river mussels, which have a restricted range of movement, furnishes the following characteristic data taken from the extended records of the river study. At Morris, 9 miles below the junction of the uncontaminated Kankakee and the Des Plaines, heavily polluted by the waters of the drainage canal which enter this stream 20 miles above the junction, the record states, "The search for mollusks yielded seven species of mussels, all the specimens dead, however, except for one collection made in Mazon slough." At the Marseilles dam, 17 miles below Morris "no living Unios were secured either above or below the dam, although the mussel-bar was diligently used in both places." At Ottawa "diligent use of the crowfoot dredge in various situations brought to light no living mussels except a bar in Fox river water just outside the mouth of that stream. Here two species were obtained alive, and dead shells of eight other species, * * * indicative of an environment still difficult for mollusks." At La Salle "thirty-six specimens, representing ten species (of mussels) included twelve living specimens of 5 species only. * * * The large proportion of dead specimens, as compared with ratios obtained farther down the stream, indicate unfavorable conditions for mussels." At Spring Valley "shells of 5 species of mussels were dredged from the bottom — all dead, however, except one specimen." At Hennepin "seventeen species of mussels were collected alive and five others were represented only by dead shells. * * * The number of living shells as compared with dead ones is in marked contrast to the conditions found above." "This was the first station at which the life of the river may be said to have found virtually normal conditions" in 1912.

As the last point is more than 60 miles from the first record given, one can see how slowly the stream assumes normal conditions in the face of the addition of such a mass of sewage as is introduced by the Chicago drainage canal. If the data for more active species had been used, they would have shown that such forms are lacking, having been driven away by the adverse conditions, or having succumbed to them. In most such cases, since the animals have not hard shells like those of the mussels to leave behind as silent witnesses of the unsuccessful struggle against an unfavorable environment, their absence would be the only evidence obtained by field observations of the unfitness of the region for life of that sort.

The destruction of the river mussels happens to be of direct economic significance since their shells form the basis of the important pearl button industry in the middle west. Even had the pollution of these waters not been sufficient to kill the adult mussels, yet these forms would have been wiped out by the destruction of the young fish to which the young mussels are attached during early stages of growth; and on which they depend also for their distribution in the stream. Moreover the condition of the mussels is a fair index of that of other organisms in the water.

To the two examples given any number of others could be added as desired; interference with natural conditions results in the destruction of aquatic organisms of all types and the most serious influence in this destruction is stream pollution. The losses are indirect as well as direct, but all contribute to reduce and ultimately to destroy the value of the stream to the state, that is to the people in general.

EFFECTS OF DOMESTIC SEWAGE

Self-Purification of Streams

It will aid in our understanding of the general problem if brief consideration is given to the effect of domestic sewage, and particularly to the purification of streams polluted with it. One sees the process carried out so commonly and often so rapidly and so well that one does not stop to wonder what becomes of all the sewage which day and night is being discharged into our streams from the rapidly increasing city population of this country. The time was for more than a century that Troy poured its sewage into the Hudson river while Albany only six miles away drew from the stream its drinking water, and indeed found it bright and clear and unobjectionable. To consider it merely a matter of dilution is to overlook the real condition. The material had been actually changed and not merely diluted, so there was no sewage in the river when the water reached Albany. But little by little the zone of pollution extended down stream until sight and smell no less than scientific study warned against the practice. The circumstances have repeated themselves a score of times or more in the course of this same stream, until now the noble river, that once ran unsullied from the mountains to the sea, shows little of its former purity and has lost much of its value to the state, if, indeed, it is not in some ways an actual menace to the welfare of the region adjacent to it.

The two questions suggested for our consideration are equally interesting and important. First, how does the river get rid of the human wastes turned into its waters and become again pure and healthful; and, secondly, why does the process fail later, or what causes the loss of the power of self purification manifested at an earlier date? Pollution and purification are evidently antagonistic processes; under circumstances either may become master of the situation, and it behooves man to know what factors control the results, that he may aid the one process or restrain the other. The application of this knowledge to the Hudson in earlier times would evidently have retained this stream in its original purity and wealth of aquatic life, while adequate, intelligent treatment of the situation may even now restore the stream to its pristine condition. C. E. Turner has recently made an intensive study for two years of the

purification of a small sewage polluted stream in Massachusetts. Of one article (Turner, 1918) discussing the results of this work, a brief outline may be given to indicate the character of the changes.

As the effluent from sand filter beds reaches the stream, a little creek of pure water and very moderate flow, the acquatic life is promptly changed. A gelatinous growth of Crenothrix, the iron bacterium, covers the entire bottom of the stream, which a little further down is black with a "pollution carpet" or "false bottom," as he terms it. In this material bacteria abound and on it one finds gray woolly masses of Carchesium, while burrowing in it are seen colonies of red worms (*Tubifex tubifex*), a typical pollution species, and Midge larvae (*Chironomus decorus*), the so called "blood worm," which is a most important factor in the removal of organic materials. At the place where the effluent enters, higher plants are lacking, but only three-quarters of a mile below they grow rankly, choking the stream and affording food and shelter to a multitude of smaller organisms, snails, isopods, daphnids, etc.

Chemical changes in the stream are rapid in this short distance, the total organic nitrogen is greatly reduced, and the dissolved oxygen, which was richly present in the clear stream and nearly absent from the polluted water at the start, has been increased despite the rapid processes of oxidation which have gone on during the interval. At three-quarters of a mile from the original pollution the false bottom no longer persists and the stream is nearly normal, though even one or two miles further down stream chemical tests demonstrate the existence of pollution. Turner summarizes this work thus (p. 45):

Importance of Biologic Factors

"It is obvious that the biological factors of stream purification are much more important than the strictly chemical and physical factors * * * Certain organisms are characteristic of an unpolluted stream. Others are characteristic of pollut on and by their presence and numbers indicate the intensity of biological activity. Some forms like rotifers and certain green algae may be present in either polluted or unpolluted water, and their correlation with each other and various plants and animals must be understood to appreciate their significance."

The changes by which animal and plant wastes are transformed and utilized are universal in nature and are applied most profitably in agriculture generally. The concentrated wastes in domestic sew-

age are similarly transformed under favorable conditions in a stream and have been used in sewage forms for the enrichment of the soil with entire success from the biological standpoint, although the financial returns have not been satisfactory. The rapidity with which these wastes in a stream are made into serviceable form for the support of life has suggested their utilization in fish culture. M. C. Marsh, formerly with the U. S. Bureau of Fisheries, has described (1916) a plan in successful operation at Strassburg for sewage disposal by fish culture. The sewage properly handled is made over rapidly into food for plants and small animals, which in turn serve as sustenance for small fish of various types. According to Marsh, the series of ponds and the dispoal plant present a sightly appearance, do not involve a nuisance and resemble any well-conducted fish culture station. As the process is delicately balanced, its successful and continuous operation depends on foresight and constant expert care. It clearly illustrates the process of nature in converting organic wastes into food materials and their appropriation by new living organisms.

This process, even to the item of its relation to fish culture, is being carried on wherever domestic sewage is emptied into a stream. In reporting biological investigation on the Illinois river, with especial reference to "the enormous outpouring of Chicago sewage into the upper Illinois" by the drainage canal, Forbes (1910) sums up one aspect of the work in this statement: "The organic wastes thus emptied into the stream are laid hold of by bacteria and protozoa and passed up by successive steps to form the flesh and bone of fishes, and thus finally those of men. The same may be said of the organic wastes of the towns along the banks of the stream."

As the quantity of waste materials added becomes larger, the point is reached when it exceeds the amount that can be handled promptly by the stream. This amount depends on several factors, viz., the volume of the stream, the rate of flow, and the character of shore and bottom. These are features which determine the quantity of dissolved oxygen in the water and its replenishment when exhausted. They determine also the amount and development of the "pollution carpet," as it is called above, and the other organisms concerned in the process. When the stream is deep and flows slowly between steep banks there is little opportunity to take up oxygen and the processes of change proceed very slowly; the contaminated area spreads down stream, and gradually transforms the stream into a sewage ditch or septic tank. This extension of the

pollution area has been measured in the Illinois River and reaches seven miles or more annually. Such a figure indicates only the significant and serious character of the change, since its precise value depends on factors so numerous and variable that the record obtained in one place cannot be used to measure the change in another.

The discussion just closed has shown that waters polluted by domestic sewage purify themselves naturally and that under favorable conditions the process is carried out with remarkable rapidity, but that when the amount of sewage added becomes very large in proportion to the flow of the stream, the changes are greatly delayed so that the pollution persists a long distance. It indicates that, with increase in the volume of domestic wastes, a condition will be reached where it is no longer possible to discharge the material untreated and at the same time to maintain an aquatic environment suitable for fish life and the propagation thereof.

EFFECTS OF INDUSTRIAL WASTES

The next question which demands consideration is the problem of industrial wastes.

Character of Trade Wastes

Industrial wastes are the by-products of manufacturing processes and are as varied in character as the industries themselves. They are relatively speaking a new factor in the relations between man and the natural environment. Starting not so very far back in history, they have risen in most recent years with startling rapidity to volumes that are proportionately large in comparison with the flow of the streams into which they are discharged. Because of their varied character, nearly every one of these industrial wastes offers a special individual problem, making it difficult to speak of them in general terms and ultimately demanding each its appropriate treatment for the correction of the evil. Furthermore, because of their very newness, their composition is unknown, as well as their action on living organisms. Nevertheless there are certain features which have been observed so often that they can be discussed as general characteristics of this type of materials.

Effects of Mixing Trade and Domestic Wastes

Serious difficulties have been introduced into the problem of stream pollution by the mixing of trade wastes with domestic sewage. It was never calculated that any system of city sewers should collect and discharge such wastes. Estimates of the character and significance of city sewage discharges are regularly based on the assumption that they contain the human and animal discharges produced in a community of the specified size, and the system provided for is based on these calculations. It needs only very meager and superficial observations to determine that in fact the sewage flow receives constant and not inconsiderable increments in the form of trade wastes. Small manufacturing plants, machine shops, laundries, garages and all sorts of other establishments creating oil, gasoline, alkaline, and chemical wastes have established direct connections with the sewers and pour into them without modifications all materials they desire to be rid of. As the city

grows the practice increases, and probably also more rapidly than the growth of the city would indicate. The reality and the seriousness of this practice has been recognized frankly, for instance by the three sanitary experts in their report to the Chicago Real Estate Board,* who say (p. 210) "A large part of the difficulty met in disposing of Chicago's sewage has been caused by trade wastes which have too freely been admitted to the sewers and open waterways. It is not reasonable that excessive burdens of cost and inconvenience should be placed upon the public by manufacturing establishments in this manner."

Furthermore one cannot doubt that the difficulty is increasing as manufacturing plants become more numerous and trade wastes more varied and abundant. In the course of the brief examination I made in certain regions of New York State during the summer of 1918, positive evidence was obtained that domestic sewage systems were carrying into public waterways recognizable trade wastes of various character and very considerable amount. It is important to emphasize this feature because it constitutes an indirect though very real contribution to the pollution of the streams, which may easily escape observation when the volume of these trade wastes at any point is combined with a larger volume of domestic sewage. As indicated in the comment of the Board of Sanitary Experts at Chicago, quoted above, this material interferes, and often seriously, with the process of self-purification which the stream has to undergo. From the biological view point its effects are apparent and even at times striking in the changes wrought in the aquatic fauna and flora. Aquatic life is wiped out and apparently does not reestablish itself readily, as it does when an excessive volume of domestic sewage is reduced. Deposits of a resistant character are laid down on the bed of the stream and deep-seated changes seem to have been brought about that make the region unsuitable for normal organisms and that endure unmodified by natural influences. Unless the unwarranted mixing of industrial and domestic wastes is checked, I am convinced that far-reaching and serious modifications will be produced in our water courses, which can be readjusted only with difficulty and after a long period of time.

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* A report to the Chicago Real Estate Board on the Disposal of the Sewage and Protection of the Water Supply of Chicago, Illinois, by Messrs. George A. Soper, John D. Watson and Arthur J. Martin. 1915.

Influence of Trade Wastes

First of all, reference may be made to the reports of State Game Protectors, which are discussed further along in this report. In a questionnaire submitted to them, one inquiry was as follows: In your experience do wastes from industrial plants affect the stream more adversely than the wastes in city sewage? Nearly one-half (49%) of the protectors who replied stated positively that they did, another ten per cent thought they did and only five per cent said they did not. About one-third (35%) had no data on which to base an opinion. That such replies were not mere guesses or simple prejudice, but were founded on evidence, is shown by the answers to subsequent queries regarding the particular wastes which in the opinion of the person reporting were most injurious to aquatic life, the places and times in which such damage had been observed, the manner in which the waste in question affected fish life, and the instances in which the treatment of wastes or their removal from the stream had proved beneficial to the fish therein. The answers contained such an amount of definite detail drawn from specific instances that no one could doubt the care with which such cases had been studied, the extended periods of time over which observations had been made, or the effort exerted to eliminate error, snap judgment, and unfair conclusions. Even though one granted that mistakes had been made, yet after all, the evidence was conclusive that such wastes exercised a powerful and baneful influence on the life of the streams.

In the second place, the industrial wastes very often, if not always, produce such changes in the aspect of the water body that even the casual observer recognizes almost at once the extreme modification of natural conditions and the conspicuous destruction of things which he had been accustomed to see in such places. The change is so radical as to suggest an entirely new condition of affairs, and is as striking as the scar on the landscape produced by a fire in a forested region or by a landslide upon a mountain side. In some cases the bed of the stream appears to be cleaned out, and in others completely covered by a film of waste or by a layer of decaying material or even of some chemical products precipitated from the waste. Even though the observer is not sufficiently informed to determine the precise character of the substances that are spread over the territory, his examination of the water forces him to the conclusion that natural conditions have been eliminated and unnatural ones have taken their place. And he is right in

believing that such changes interfere with the natural existence and proper reproduction of aquatic life.

In the third place, many of the substances discharged in industrial wastes are known to be powerful poisons, so that one is forced to say in advance that their action on living organisms will be distinctly unfavorable. In a given case it may be that the degree of dilution is so great that larger and more resistant species of plants and animals are not killed outright. Yet even in these instances the effects of such chemicals are injurious and the vitality of the organisms is lowered, the reproduction of the species is interfered with, or the sensitive stages of early life destroyed. Thus in one way or another the life of the stream is stunted and slowly eliminated until, if the process is unchecked, the stream becomes a desert. These conclusions do not rest purely on inference or even on imperfect field studies, but are supported and justified by experimental work in scientific laboratories, and some of the evidence secured in this way will be given in a later section of this report.

Industrial wastes constitute a large and increasing element in the pollution of our streams. They form a menace to the aquatic life that is most serious. There is no natural series of changes which render them inert or transform them in a short time into materials useful in the economy of nature. Each one offers in itself a problem as to, first, its exact effect on aquatic organisms, and, second, the treatment demanded to eliminate the evils it has caused.

It should be noted as an exception to the general statements made above that industrial wastes sometimes exert a mere mechanical influence on the conditions of the water-body into which they are discharged. Prejudice has long existed, undoubtedly with good reason, against the general habit of sawmills in earlier years when they were accustomed to turn loose the waste sawdust and trust to the current of a stream to dispose of it. While recent experiments have shown that the particles of sawdust floating in the water are not, as was formerly supposed, directly detrimental to fish, and do not interfere in the least with their respiratory processes, yet there remains little doubt that in other fashion the sawdust waste is of ominous significance for them and the other life of the stream. The sawdust soon becomes water-logged and settles in thick masses as a loose cover on the bed of the stream. Great areas are covered over by it, all sorts of attached organisms are smothered, and the smaller animals are destroyed for lack of food and shelter. Soon the mass itself begins to decay, exhausting the oxygen from the water and

releasing poisonous products. The stream, originally characterized by an abundance of clear, pure-water animals, is so modified that it can afford existence only to those which live in a polluted environment. Furthermore, the possibility of fish reproduction is very definitely interfered with, for the eggs that are deposited sink into the sawdust or are covered by it with the shifting of the bottom by the current. Those fish eggs which are abandoned and must depend upon chance for their development are unfortunately suffocated. Even those eggs which are watched by the adult fish, so that the nests are kept from being covered by the floating sawdust, find the water unfavorable for development and die off in large numbers. Finally the fry, if any hatch, seek in vain for food and shelter. Valuable fishing in both lakes and streams has been totally destroyed in this way.

From the tanneries are discharged large amounts of carbonate of lime, which settles over the bottom in the form of a white film that is inimical to the smaller organisms of the water and apparently to the fish also. The wastes of steel mills are similarly deposited in characteristic form on the stones and gravel of the bottom. While here the character of the fluid wastes themselves is promptly destructive to aquatic life, because o ftheir acid character, so that the deposit itself is of lesser significance, nevertheless it plays some part and is of especial sigificance in retarding the recovery of the stream.

Wastes which are discharged from oil refineries are particularly inimical to aquatic life. They frequently form a firm adhesive film, covering the stones, bottom, and all other objects in the water. This covering seems to be a thin layer of tar, and is very resistant, so that even after the cause of the pollution has been removed, there remain visible signs of the pollution for a long time. These wastes are so resistant that it is difficult to find any way to purify them and no type of industrial waste is more serious to aquatic life. Such wastes come from gas plants as well as from oil refineries, and are unfortunately widely disseminated. The serious character of their influence is vividly shown by field studies in a region where they are discharged into a stream. Many observers have seen a beautiful little brook rich in fish and other aquatic life transformed into a barren, unsightly, stinking stream, merely by the addition of wastes from a small town gas plant. The experimental data confirm these observations fully and should be cited here in part that the matter may be clearly comprehended.

Toxicity of Gas House Wastes

Marsh (1907) showed that tar is extremely poisonous to perch and bass. Illuminating gas is also very toxic. How small the amount actually is has been determined experimentally by Shelford (1917: 391) who states that "it may safely be said that ten to twenty parts per million of this waste [from a city gas plant] killed a 4–5 gram *Lepomis humilis* [the small sunfish] in an hour." Wells (1918, p. 568), in summarizing his experiments on the two gases, says that both CO and CO_2 are poisonous to fishes, though the former is very much more deadly. So far as CO_2 is concerned, fishes are verv sensitive to small changes in the amount of it in the water and seek to avoid harmful concentrations by turning away from them. Fishes do not, however, appear to detect CO in the water and enter concentrations of it that kill them in a few minutes. These concentrations are such as would follow the introduction of gas house wastes into water bodies. At the close of an extended series of experiments in the reactions of fishes to wastes, Shelford (1917:392) writes that "much of the danger to fishes from pollution of streams, especially when the pollution is local, is determined by the reactions of the fishes to the polluting substances. Fishes turn away from dangerous substances which are normally found in their usual environment, but with strange or unusual substances, such as are thrown into streams by gas-works and other industrial plants, they frequently enter and follow up to points where the concentrations are fatal, or fail to recognize the dangerous substance at all and often stay in it until they are intoxicated and finally die there." In support of this conclusion he shows the results of experiments in a series of charts and graphs. Fishes are positive* in their reaction to gashouse wastes in all concentrations which Shelford used in his experiments. The complexity of the questions involved is also shown by the statements of Wells, who determined that fishes vary much in power of resistance to different substances with the season. From the middle of June to the end of July resistance is least, and such fishes as the cyprinids die almost as soon as they are taken from the water. The resistance rises slowly from this time to September and then more rapidly until at the maximum in March and April all fish are very resistant. As the breeding season comes

*An animal is said to react positively to a stimulus when it moves towards the source of the stimulus and negatively when it moves away from the source. The positive stimulus attracts the animal whereas the negative stimulus repels it.

the resistance falls. It was not possible to determine the effect of this factor on the breeding of the fish; but this is evidently a subject of very great importance.

It would be possible to bring together data concerning the effect of other kinds of waste on aquatic life, but this would prolong the present discussion too greatly and the instances already elaborated are adequate to show the general questions involved. I think they are also sufficient to demonstrate the value of biological tests in securing a proper estimate of the effects of stream pollution, and the ways in which biological studies may be utilized in the solution of the problem.

THE RETURN TO NATURAL CONDITIONS

Slowness of Return to Normal Conditions

Before passing to consider another topic, I should like to call attention specifically to the fact that a stream area from which natural life has been eliminated by pollution is extremely slow in recovery. In the questionnaire which was sent the game protectors, discussed elsewhere in this paper, they were asked, among other things, how long it took an area that had been adversely affected by pollution to become restored to normal conditions, and a number of them said in response to this question that the stream was never restored. This is the careful judgment of men trained to outdoor life and accustomed to observe stream conditions and to follow changes in them from year to year. Perhaps it would be wrong to accept this statement in an absolute and mathematical sense, but we shall not go far astray in taking it to be generally true. Once the life of a stream has been wiped out, the process of recovery demands a very long period of time, if, indeed, the stream is ever restored. Of course, no start can be made until the causes for the destruction of the aquatic life have been removed, and thereafter the restoration of normal conditions depends upon a series of factors that it is not difficult to outline in general, but impracticable to calculate in definite fashion. It is evident, without further argument, that the longer the pollution has been going on, the farther it has extended, the greater the area of the water involved, and the larger the amount of deleterious substances that have accumulated, the longer it will take for those changes to be carried out that will eliminate the poisonous substances and restore the bottom and the water to a condition in which life is possible again. Repopulation of the area will naturally be brought about by the migration of animals of various sorts from contiguous territory into the restored region, and, of course, also, by the planting of such organisms as may be introduced designedly in an effort to replenish the life of the water. Ordinarily, men have not attempted to do more than to plant fish, and usually have introduced them in young stages. It is, of course, worse than useless to do this until the food supply has been provided in one way or another, and any failure to consider this aspect of the question merely means that the fish which were introduced would starve to death and the experiment

be brought to an unfavorable end. Fortunately one of the prominent elements of the water fauna replenishes itself very rapidly. I refer to the insect larvae that in multitudes inhabit different sorts of environment in our water bodies. First and last they far exceed in variety any other group of animals found in the water. For the most part the adults live in the air, and are possessed of means of flight sufficient to distribute them over considerable areas. As soon as a bit of water becomes tenantable, there will be deposited in it by the flying adults the eggs which will yield in the appropriate time a supply of aquatic larvae. It is true, also, that the eggs of some insects will be deposited in the water even though it is not in condition to furnish them with a proper environment for development; this is an effort, as it were, to utilize all possibilities of existence and to repopulate the given area before it has actually reached the condition in which existence is possible.

BIOLOGICAL EXAMINATION OF WATER BODIES

Need of Considering Entire Picture

It seems worth while to review the general method of collecting data on stream conditions that should be pursued in actual field work. One cannot emphasize too strongly that a fair judgment concerning conditions can be obtained only by taking into consideration the entire picture which presents itself to the observer. Single elements of the aquatic situation may be modified by one circumstance or another, and the student who relies upon any individual factor to determine the value and character of the water area will be frequently led astray. If one starts with the point at which the stream of waste empties into the natural water channel and follows down stream he will observe that, especially if the effluent is colored, it is easy to trace the gradual mixture of the waste with the stream water as it spreads itself towards the opposite bank as well as down stream. The bottom is often colored and the waste furnishes floating particles which, in addition to the color tone already mentioned, aid the observer in tracing the spread of its influence over the water body. These general appearances are readily followed at ordinary stages of water. They become very conspicuous during low water conditions, and are more or less concealed in times of high water or when the stream is turbid with the surface run off that is carried in after storms. One can follow out in the way just indicated the area brought under the influence of the effluent, and to determine the biological effect one turns next to the study of the living organisms within the area involved. It has been customary in the past to base conclusions upon observation of the fish themselves, but one should not and cannot place dependence upon this or any other single test object. As a means for determining the suitability of the water body for the existence of fish life and its favorableness for the multiplication of fish species, it is better to study the small organisms rather than the fish themselves. The fish are evidently less subject than are the smaller organisms to the control of the immediate environment and better able to change continuously

their position, as well as to undergo for a limited period unfavorable conditions without really adapting themselves to the situation.

For other reasons, also, study of the fish in the stream alone gives unreliable results. In response to the complaint that the pollution of streams has affected the abundance of fish life, it has often been urged that the real reason for the scarcity of the fish fauna is to be found in the multitude of fishermen and the methods that they follow, rather than in the unfavorable conditions of the aquatic environment. One hears strong arguments advanced in the effort to establish that contention, and it may well be true. In many regions the number of fishermen has increased beyond the possibility by natural methods of reproduction to supply the draft upon the waters. Men have also caught more fish than was reasonable or legal, and have used nets, traps, dynamite and other means of obtaining fish to such an extent that the fish supply in certain waters has been reduced pretty nearly to zero. There are other factors also which tend to reduce at a given time the number of fish in a certain stream or pond. One may refer, first, to the migrations that fish carry out for reproductive purposes or in response to seasonal changes of water temperature and depth, as well as those which result from mechanical disturbances and from the addition of chemicals and wastes of various kinds.

Hence to base any conclusion upon the number of fish which happen to be present in the particular region at a given point of time is evidently to run the risk of serious error. A stream may be well adapted to support fish life, and adequately supplied with the conditions necessary for the existence of the fish, even though it be entirely without, or nearly entirely without, a fish fauna. It is however, not difficult to distinguish between those places in which the absence of fish may be due to the pollution of the stream and those other points at which the lack of a fish population is to be explained on some other basis.

Natural Aquatic Life

The method for distinguishing between such cases in general will be readily understood when one considers the general biological condition of the water. Each water body contains, under natural conditions, a varied assortment of living organisms, provided it furnishes the possibility of existence for the fish themselves. These other

organisms constitute the primary or secondary sources of food supply for the fish. Together they make up the biological complex of the water. Just as one would not expect to find large land animals in any region which was devoid of vegetation and smaller living organisms, and which presented to the eye nothing but an extended area of bare soil, so underneath the surface of the water one need not expect to find conditions right for fish existence if there are no other organisms present and no varied associations of living things, both plants and animals, to provide the food supply of the larger forms. And just as one can distinguish on the land between desert conditions which are primary and natural on the one hand, or secondary and created by untoward conditions on the other hand, so one may differentiate equally between the aquatic desert which is natural and represents a region unfitted for fish existence on one hand, and those conditions which are acquired and due to interference with natural conditions on the other hand. If the fish have all been caught off or driven away, then one would still find the smaller animals and plants, provided conditions of existence still remain favorable. But if the character of the water and the bottom have been so modified by the introduction of foreign materials that they no longer afford opportunity for the development of these smaller organisms, then by the absence of such forms of life one would demonstrate clearly and positively the fact that water has been rendered unfit for fish existence.

Devastation on Land and in Water

One can furnish a ready example from the surface of the land to illustrate the point in mind. In the midst of wooded hills a forest fire has swept over a given area and reduced the land to bare soil, with perhaps fragments of half burned wood and ashes which soon disappear with the storms. The region stands out in sharp contrast with surrounding areas where the growth of plants and the presence of animals of various types indicate favorable conditions for existence and the ability of the territory to support a varied population of living things. Under the surface of the water the same thing has taken place at certain points. The inflow of chemical wastes has driven away the fish, has eliminated oxygen from the water, has destroyed the smaller organisms, both the plant and animal, and has left either a waste or a highly specialized and peculiar chemical

environment in which only certain strange types of living things can exist, namely those which have the power to perpetuate their existence under the unusual chemical conditions present.

If we attempt to picture to ourselves similar conditions on the surface of the land, we see how imperfect would be conclusions formed in the same way that those regarding pollution are sometimes based upon observations concerning the occasional presence or the absence of fish. In an area devastated by forest fires one might frequently see wild animals of various sorts on the land surface or flying in the air above it. Such movements might be in certain regions very common if the area involved was not large, and even where it was extensive the occurrence would be by no means peculiar. But it does not suggest to our minds that the territory itself is suited for the existence of these animals. In fact our eyes take in at once the general conditions. We note the soil stripped of vegetation, the evidences of the fire in ashes and charred fragments of wood, and despite the presence of occasional individuals of the higher types of animals, we never question the fact that the area has been devastated and its life wiped out.

The situation may be duplicated very closely in the water. The fish are the largest, most powerful, and most active of all water living organisms. The larger game fish with which we are most familiar are the most active of all in their movements in search of food. Consequently, it cannot be too strongly contended that the presence or absence of these forms does not yield positive and adequate evidence with regard to the pollution of the stream or the general condition of the aquatic environment. Yet concerning streams that are under examination with reference to the quality of the waters, one frequently sees a statement to the effect that fish were seen at a given point or were swimming through a certain supposably polluted section. It is claimed, consequently, that though the appearance of the stream had been changed, the waste was not serious because fish were found in it and around it.

Susceptibility of Fish

In this connection it may be appropriate to call attention to the difference in susceptibility between different species of fish. While we are not in position to make an absolute statement on this point, it appears from recent published experiments by Wells and Shelford

that fish vary widely in their resistance to pollution and in their indifference to the presence of waste materials in the water. Most of all, our valuable food fish are exceedingly sensitive, but some other fish continue to live, if not to thrive, under conditions in which certain sorts of pollution are very conspicuous. I include here a table taken from Wells (1918) which gives knowledge on this point.

TABLE OF RESISTANCE (After Wells)

Indicating the relative resistance of the more common species of fishes to be taken in the waters of Northern Illinois, together with data as to the best type of ecological environment for each species. In column 2 the resistance of the least resistant species is arbitrarily taken to be unity.

Species of Fish	Relative resistance	Best place to collect
Labidesthes sicculus (Brooksilverside)	1	Small rivers and clear shallow lakes. Prefers sandy bottom.
Etheostoma coeruleum (Rainbow darter)	2	Among the stones in the ripples of creeks and small rivers.
Moxostoma aureolum (Redhorse)	2.3	Sandy-bottomed pools in creeks and small rivers.
Catostomus commersonii (Common sucker)	2.4	Pools in creeks and small rivers. Prefers bottoms containing some sand.
Notropis atherinoides (Shiner)	3.0	Common in lakes and rivers.
Semotilus atromaculatus (Horned dace)	4.0	The headwaters of small creeks. In vegetation along bank.
Chrosomus erythrogaster (Red-bellied dace)	5.0	Small clear creeks. Along with horned dace but does not go up stream as far. Often in vegetation along bank.
Micropterus dolomieu (Small-mouthed black bass)	5.0	Swift streams; clean bottom. Small deep lakes; cold water.
Micropterus salmoides (Large-mouthed black bass)	6.0	Sluggish rivers and small, shallow lakes with mud bottom.
Pimephales notatus (Blunt-nosed minnow)	6.0	Pools, mud bottom, in creeks and small rivers.
Hybopsis kentuckiensis (River chub)	7.0	Creeks and small rivers. Swifter parts of pools.
Notropis cornutus (Common shiner)	7.0	Creeks and small rivers. Swifter parts of pools.
Pomoxis annularis (White crappie)	8.0	Wide distribution. Abundant in ponds, lagoons, and all sluggish water.
Pomoxis sparoides (Black crappie, Calico bass)	8.0	Practically same location as for white crappie.

Species of Fish	Relative resistance	Best place to collect
Ambloplites rupestris (Rock bass)	10.0	Clean-bottomed pools with rocks. Creeks and small rivers.
Perca flavescens (Yellow or American perch)	10.0	Abundant in some lakes. Also in larger rivers but not in creeks.
Lepomis cyanellus (Blue-spotted sunfish)	15.0	Pools in creeks. Often with mud bottom.
Ameiurus melas (Black bull-head)	45.0	Ponds; pools in small creeks. Mud bottom among vegetation.

" While in the table only eighteen species of fishes are listed, the comparative resistance of other species may be estimated by comparing their resistance with that of some one of the listed species. By placing a species of unknown resistance in an experiment with one of the species given in the table one may obtain results that will make it possible for him to compare the resistance of the unknown species with that of any of the species listed. It should be pointed out also, that fishes of the same large taxonomic group have in general a similar power of resisting detrimental factors. Thus, the darters are a group possessing for the most part a low ability to resist untoward conditions. The minnows (Cyprinidae) are fairly resistant as a group; the sunfishes are more resistant than the minnows; and the catfishes are notably our most resistant group of fresh-water fishes. The place of an untried species in the resistance table can be reckoned more or less accurately by placing it with the listed representatives of the taxonomic group to which it belongs.

" From column 3 of the table it will be seen that the resistance of the fishes is rather closely correlated with the type of environment which they inhabit. The more resistant species are found in ponds, shallow, muddy-bottomed lakes, or in the stagnant pools of streams. These are the fishes which one sees in aquaria. They are able to withstand increased temperature and wide fluctuation in the oxygen and carbon-dioxide content of the water, and to some extent are able to live in the presence of the excretory products of their own metabolism. The stream fishes proper can not do this, and therefore die when placed for any length of time in standing water." (After Wells, Bull. Ill. State Lab. Nat. Hist., 11:567–568.)

Bacteriologic Tests

There is need to test in some accurate way the character of a stream and the methods most generally employed have been bacteriological and chemical. Bacteriological methods are developed with reference to determining the character of the stream from the standpoint of public health, which usually is considered to concern only the human species. Consequently, determinations are made of certain definite kinds of bacteria that are inimical to human welfare, and little or no attention is paid to other elements in the situation. It is conservative to say that our knowledge regarding the bacteria is not adequate as yet to determine all of the forms found, or to

estimate their relations to the different kinds of life which are involved in the stream. Furthermore, the processes are time consuming and expensive so that their general application to water bodies is attended with evident difficulty.

Chemical Tests

Chemical tests determine for us more or less readily and rapidly the constituents of a given water mass. This again is somewhat tedious and expensive. Furthermore, we do not by any means always know the effect upon living organisms of a given chemical substance, and, as has been found by experimental procedure, the effects of various substances differ according to the concentration present, and also, in relation to the other chemicals which may be associated with this original substance. Consequently, the situation is exceedingly involved and much more study will be necessary before it is profitable to use such tests widely and generally in the testing of water bodies.

Those who desire to find a more rapid means of testing approximately what the character of a given aquatic environment may be, naturally seek some sort of superficial and readily determined feature as an ear-mark, and have found this in the relation of the environment to fish life. This is a rough and ready method of determination and not without its merits, though there are distinct limitations to its employment. If one follows along the bank of a stream or lake, or traverses its surface in a boat, and finds large fish and schools of smaller ones, he inclines to infer from the number and distribution of these animals the condition of the water. However, the habit of relying on a single criterion in judging such a complex situation as a natural environment is dangerous. Perhaps there is no other way to explain an abundance of fish life than the satisfactory condition of the water for fish existence, though it is easily possible that, unless the observation is repeated at different times, the condition may be the result of accident rather than a general characteristic of the situation.

Effect on Fish of Changed Conditions

On the other hand, the total absence or extreme rarity of fish life in any body of water would be good evidence that the aquatic environment was unsatisfactory for them, for it has already been explained that over-catching will account for a reduction in the supply of food and game fish, but if it affects at all other types, would rather tend to multiply than to reduce their numbers. How-

ever, when one has to contend with an intermediate situation there is the greatest difficulty in deciding from the evidence obtained from observations on fish alone what is the cause of the condition. Fish are sufficiently active animals that they move into unoccupied territory and move out from it under varying circumstances and with considerable promptitude. How they conduct themselves in reference to highly polluted streams is well shown by observations which may be cited here. For the clearer comprehension of this instance, let us recall that the city of Chicago discharges its wastes into a huge drainage canal which at Lockport empties into the Des Plaines and this latter stream in turn joins the Kankakee a few miles below to form the Illinois river. These streams, and particularly the last mentioned, has been under biological observation by the Illinois State Natural History Survey under the direction of Professor S. A. Forbes for some thirty years, so that records were made of its character long before the construction of the drainage canal and the addition to its waters of the highly polluted Chicago sewage. The Illinois river has always been an important source of fish for anglers and commercial fishermen. More recent records demonstrate how the fish conduct themselves towards the radically changed conditions and the observations are so pertinent to this inquiry that I propose to discuss here their finding for comparison with records made by various New York state officials at different places in this state.

Fish Shun Pollution

The definiteness with which fish avoid polluted waters and the effects of such waters on them can be well shown by some citations from observations on the Illinois river (Forbes and Richardson, 1913). In the sanitary canal at Lockport they record (Sept. 1911) "a few small shiners (*Notropis atherinoides*) one to two inches long were alive in the water though in a dying state; but all the larger minnows of this species, * * * were stranded dead along the shore. In the cooler weather of November, 1911, a larger proportion of the shiners were alive." In the Des Plaines at Lockport "no fish were seen here in September, the water being much too foul for even the most indifferent species." In November they found "many shiners, nearly all alive but mostly in a dying state, as if they had been carried down by the current from above and overpowered by the toxic contents of the stream." In August and September, 1912, one could see "a marked contrast between the two sides of the river, due to the fact that the water of

the east side was badly contaminated by a waste ditch flow from the sanitary canal; * * * in the Cladophora of the west side were many live minnows, sunfish, etc." It is worthy of note that I found conditions in the upper Hudson at some places identical with this in that near the discharge from a large mill aquatic life was entirely lacking while on the other bank, where the water was as yet unmixed with the wastes, one could find both plant and animal organisms of various types.

To return to the record of fish in the Des Plaines river, just before it joins the Kankakee to form the Illinois "no fishes were found either dead or alive" in summer or in fall collecting. At Morris 9 miles below, "no fishes were seen or heard of in the Illinois during July, although they were abundant in Mazon creek and in the slough at its mouth which opens into the Illinois at Morris. Carp were noticeably numerous in this slough and could be seen any sunny morning lined up along the edge of the river current, occasionally venturing into it a short distance, but quickly returning. * * * By October fishes had begun to appear to some extent in the river even along the northern or contaminated side, where a few young perch, shiners, straw colored minnows, and a single top minnow were taken in places protected from the strong current. * * * An examination of the stomach of these specimens showed that none of them had recently taken food." "February 28, a neighboring farmer found a 15 pound carp on the ice near the north shore. The fish was probably sick or suffocated and trying to get air." In 1912, "seven fish were taken at this point in all — five of them black bullheads. * * * The river here was in fact practically destitute of fishes and the few taken were in close proximity to the Mazon slough. Moreover, some of the bullheads were "fungused" or in otherwise unwholesome condition."

"The yield of our fishing operations was somewhat more varied at Marseilles than at Morris but only in the immediate neighborhood of small creeks and springs where the water was locally or temporarily more tolerable than in the main stream. No trace of fishes was found above the Marseilles dam during July or August, 1911. * * * In November and December many young perch, shiners, a black bullhead and a young carp were captured. * * * In August and September, 1912, conditions were similar. * * * Fishes were caught [only] within or near the mouth of a small creek on the northern side. * * * On the night of August 19, a heavy rain, which flooded the small creeks, washed fishes out into the river

where they became sick from sewage and could be picked up easily with a dip net. The following morning a 3 pound carp, 2 hooked dace (*Semotilus atromaculatus*), and an orange spotted sunfish were obtained in this way. "In August 1912, * * * below the dam * * * we got a greater variety of species in shallow water along shore near the mouths of small tributaries. * * * A comparison * * * makes it probable that most of the specimens taken from the river here were immigrants from the creeks."

At Ottawa in August fish were much more abundant. "From a comparison * * * it is plain that Fox river water was greatly preferred by fishes at this place and it seems likely indeed that most of the specimens taken at this point had come into the [Illinois] river from the Fox." At Starved Rock as a result of extensive collecting "it seems that the fishes taken here represented the normal river stock at this place with practically no immediate admixture from small tributary streams." "At Hennepin we found commercial fishing in progress in both the river and the adjacent lakes. This was the first station at which the life of the river may be said to have found virtually normal conditions."

While Forbes and Richardson found as shown above that the large majority of fishes were driven away by pollution, or if carried in by chance were unable to sustain themselves in the polluted sections of the Illinois river, there was at least one exception to the rule; indeed, so far as their experience went, only a single species of fish was an exception to it. The common shiner (*Notropis atherinoides*) was often collected in numbers when no other fishes were found; as a result of their experience, these authors say that this abundant lake and river minnow is "unusually tolerant of polluted waters."

Minnow Test

Chemical and bacteriological methods have rarely been employed in stream examination by men associated with work on fish problems. They have, however, used fishes as an index of stream conditions, and have commonly employed the so-called minnow tests as a basis for deciding whether, for instance, the pollution in a given stream reaches the extent specified in the Conservation Law and consequently whether the discharge of the wastes should be prohibited. The test probably owes its popularity to the ease with which it may be applied and, when the conditions of its use are safeguarded, one must recognize that it is a reasonably satisfactory

test, even though it be rough in itself and though its use be distinctly favorable to the cause of the manufacturer rather than to the protection of the fish.

In order that the test may be properly applied, it is necessary to take a group of minnows and divide them into two parts, placing one in a cage or float that is anchored in the stream above the point of contamination and another in a similar cage or float that is placed in the stream enough below the point of entrance of the waste material that one can see it is reasonably mingled with the waters of the stream proper. If after a short period the minnows in the lower cage are dead, the upper cage is then examined and, if the fish are living, it is transferred to the position of the down stream cage. The death of this second lot of fish will then establish very positively the fact that the wastes are injurious to the fish life in the waters.

Serious Conditions Proved by Test

Some attention must be paid to the variability of this test and its relative value in determining the injurious character of trade wastes. The minnow is a small fish and generally is of a type fairly sensitive to water pollution. It does not represent the varieties that are most sensitive, like the trout, and on the other hand it is far more susceptible than such fish as the carp and bull-head, which are known to be relatively indifferent to pollution. One should not forget that Forbes found the common shiner was "unusually tolerant of polluted waters," and this species if collected by any persons and used for the test would vitiate the results. It is recognized, furthermore, that the most sensitive stages in the history of any fish are those of its youth, the fingerling and fry stages being far more susceptible to injurious influences than the half-grown or full-grown fish. Accordingly, if the effect of the wastes on minnows or young fish collected as such is clearly injurious, then one can confidently affirm that no stronger argument is needed to establish the serious contamination of the stream, in that any effect produced in the short time that has usually been utilized for these experiments is in itself conclusive beyond possible criticism. It will readily be recognized in a moment's consideration that, undoubtedly, many contaminations are injurious to fish in the long run and yet these influences would not display themselves in any measurable fashion within the brief period of such a test.

Shelford maintains that to make safety tests reliable in character, fish should be able to live at least one month in water under standard

conditions, and these will include, of course, the regulation of the volume of flow, the degree of pollution of the waste, the temperature of the water, the abundance of oxygen, carbon dioxide, etc. It is a well established fact that the temperature of the water affects the sensitiveness of fish and conditions which may be injurious at one time are not serious in their effects at another. Furthermore, Wells has shown most distinctly that an abundance of oxygen tends to reduce the toxicity of various other substances in solution, especially of carbon dioxide.

Effects of Prolonged Influence

In order to reach a more accurate measure of the injurious character of polluted waters, one would have to take into account the effects of the prolonged influences of a waste on the fish. We recognize generally from our study of the human race that deleterious influences are frequently cumulative in effect and that even small quantities of poisonous materials, acting upon the organism over a long period of time, will produce serious and even fatal results. In a similar way extremely diluted chemical substances, which might seem in an experiment of brief duration to have no effect whatever on fish living in them, will, undoubtedly, in given cases be found to affect adversely the condition of fish subject to their influences continuously for a longer period of time. This question is one on which little or no experimentation has been made. We are forced to speak of the conditions in terms of analogy, basing our conclusions upon the results that are well known in the records of human disease and have been confirmed in individual cases among other animals. The kinds of materials which exercise such deleterious influences, the amounts adequate to produce the results feared, and the other conditions under which they must work are, however, not fully known.

Limiting Factors

A considerable number of other factors should also be taken into account in connection with the minnow test. Unless care be exercised in determining the time and other conditions under which the test is made, one may very easily get a set of conditions that is calculated to prevent rather than to demonstrate the actual effect of the pollution. The influence of a waste discharged into a stream must be measured by its effect under most unfavorable conditions, for those are the times in which the fish life will be injured or

destroyed most easily and most completely, and consequently the times at which the character of the stream life is determined. The lower the flow of the stream, the greater the probable effect of the pollution upon fish. With varying conditions in the effluent, such as alkalinity at one period and acidity at another, that time should be selected for the experiment which gives conditions least favorable for fish life. Similarly, the period of the minimum percentage of oxygen in the water indicates the moment of lowest resistance on the part of the fish, while other elements, such as the shortage of food, which tend to reduce the vitality of the fish, are also important factors in determining the effect of wastes on fish life. It will be noted that a number of these conditions are probably accentuated at times when the water is covered by a coating of ice and consequently the most serious effects of stream pollution will probably be found when in the winter season the diminished stream flow and the ice cover tend to emphasize the injurious character of wastes discharged into the stream.

The foregoing discussion is sufficient to indicate the extreme limits of usefulness of the minnow tests. Much more accurate experiments have been made on the susceptibility of fishes to various specific influences and it has been possible to determine thereby some important questions concerning their individual responses to particular chemical substances. These experiments have been carried out in the laboratory. They require compl.cated apparatus and students have been misled in applying them because of the unsuspected introduction into the natural situation of other factors than those on which the experiment was based. It is evident that lowered vitality due to confinement may easily be confused with lowered vitality due to the influence of the chemical used in the experiment. Furthermore, in order to cover the wide range of substances which may enter into consideration in connection with industrial wastes, the amount of time involved in experimentation is extreme and the expense not an inconsiderable factor, so that the method can hardly find universal application. Yet one must emphasize the fact that these experiments are important and in the hands of Shelford and his students have yielded very valuable results for the general orientation of the worker in dealing with the problem. Indeed, one may say they are indispensable and should be generally employed wherever it is proposed to test a new problem or to determine whether a proposed modification of some industrial waste will render it innocuous to aquatic life.

Results of Experiments in Polluted Streams

On the other hand, it must be pointed out that experiments have already been carried out on a grand scale in connection with wastes from many industries, and an examination of the territory subject to the influence of the wastes discharged will yield better evidence than any such laboratory experiment, for in such a place one can see not merely the results of brief exposure to the influence of a waste product, but rather the cumulative effects of long continued stimulation by these substances under the varying influence of winter and summer, low water and freshet, open water, ice-blanket, and all other conditions that obtain in the given region. A study of the territory will show what has been the result of the experiment and the records of the manufacturing plant will probably always furnish evidence at least as to the length of time that the waters have been subject to this influence. In most cases it will also be possible to determine in rough fashion from the manufacturer's data what fluctuations in the composition of the wastes have occurred within that period. The unfortunate total destruction of the organisms characteristic of pure waters and their replacement by species which are equally characteristic of polluted streams, as observed in various places, is incontrovertible evidence of the effect on aquatic life of this particular waste. While in the case of a request for a permit to discharge new industrial wastes into a stream the method of laboratory experimentation should always be utilized to determine the probable result of the practice, yet in the instances where the experiment has already been tried the results displayed in the stream are important enough to demand careful examination and detailed record in order that the evidence may be available for use in dealing with this and similar plants in future.

Our general knowledge of animal life would lead us clearly to the conclusion that certain stimuli which do not appear to have an immediate serious effect upon animal life may clearly be harmful if their influence is exerted upon the same organisms continuously over a long period of time. Bad air and bad water undoubtedly influence in a similar way the organisms that are confined to the one or the other environment. It is impossible to doubt that dilute poisons in the water exert precisely the same sort of an influence on the fish and on the other organisms contained in it. It would be impossible to give here a complete summary of all the observations and experiments that are on record with reference to the influence of pollution on aquatic organisms or even on the fishes alone. I shall,

however, cite later a few prominent records with reference to the reaction of fishes to various sorts of polluted waters. In general it may be said that, like other animals, fishes sometimes manifest no response whatever to an abnormal and unwholesome environment. In the majority of instances, however, they indicate the influence by moving away from the source of the pollution or refusing to enter upon polluted waters that lie directly in their natural path of movement. In some cases, however, they manifest a desire to enter the polluted waters and move towards the source of the pollution, remaining in the danger zone until they are overcome by the effects of the pollution. I have already called attention to observations of Forbes and Richardson on the Illinois river.

Powers of Resistance in Fishes

The general features which enter into the case are summarized by Wells (1918) thus:

"The resistance of fishes to hurtful conditions varies with the species, with age (or size and weight), with the individual (that is with physiological state), and with the season. Practically all of the fishes worked with are least resistant just after the breeding season, or in the months of June, July and August (see Wells, 1916). In September the curve of resistance begins to run up, and it continues to rise throughout the winter months, reaching its maximum in March, April and May — that is, at the beginning of the breeding season or just before. The relat ve resistance of species does not seem to vary greatly with the season. Just how much species vary in their relative resistance to different harmful factors is a matter for further investigation. The work so far, however, indicates that if species 1 is more resistant than species 2 to factor a, it is fairly safe to conclude that it will show a greater resistance to factor b also."

PRELIMINARY SURVEY OF STREAM CONDITIONS IN NEW YORK STATE

It is important to outline briefly the work that was done to to the pollution of its streams. An examination of the files in the office of the Conservation Commission brought to light numerous reports made from time to time by various officials and employees of the Commission with reference to the pollution of streams at individual points. It revealed also a record of prosecutions carried on against violators of the law. The evidence thus adduced served to demonstrate the amount and character of the pollution found and the judgment of the courts with reference to the relation of the cases to the law as it stands.

General Knowledge

The condition of the larger streams in the state has been widely and frankly recognized. Indeed the language used with reference to the conditions that prevail in the Mohawk and Hudson is so emphatic as to leave no doubt concerning public opinion on the conditions in those streams. Various surveys have been made and official reports printed which demonstrate the situation equally and in greater detail. Industrial wastes have been discharged in sufficient quantities to wipe out entirely the life in several streams in such immediate and conspicuous fashion that citizens reported the finding of dead fish in large numbers along its banks. In other places the accounts demonstrate the presence during considerable time periods of chemicals and of products of decay so offensive as to have attracted general comment and protest. These reports ascertain the facts of the situation in New York state with reference on file and records in print are not by any means confined to one locality or to a single type of industry. They concern the eastern, the central, the western, the northern, and the southern sections of New York state and come from practically every drainage basin. It must also be said that in some cases such conditions originate in neighboring states and are brought into this state with natural stream flow while in other cases New York state is responsible for the pollution of streams that pass beyond its borders and affect adversely neighboring commonwealths.

Reports of Game Protectors

With a view to securing more complete information on conditions as they stood at the time, a questionnaire was sent to each of the

game protectors accompanied by a request that the blank should be filled out and returned to the office of the Conservation Commission. From these questionnaires which were submitted without comment on the purpose and indeed without the knowledge of the person replying that any study of the subject was in prospect, we could gather a mass of definite facts both interesting and significant. New York has in the state game protectors a valuable permanent force of men devoting their time to a study of natural conditions. While not technically trained in science, they are accustomed to use their eyes and heads in the observation and interpretation of natural phenomena. They are not likely to be misled by appearances, and they know both how pure streams look and what living things should be found in them. Great weight should be laid on their findings as to the condition of streams in the localities with which they are familiar.

From the even hundred replies received to the questionnaire, valuable information was obtained as to the amount and distribution of stream pollution in the state, and as to seasonal and other variations that it undergoes. Evidence was also furnished on the damage done to riparian owners as well as to the aquatic life. These replies have been analyzed and are on file so that they can be still further utilized in the work of the Conservation Commission. Consequently it is probably not necessary to discuss them further at this point. Containing as they do specific reports concerning every part of the state and every variety of industrial waste, with numerous definite suggestions in regard to methods of improving conditions, they are in my opinion an invaluable aid to the further study of stream pollution in New York state and to its elimination.

Personal Observations

In order to be clear that the observations were reported with reasonable accuracy and that the situation had not been misinterpreted through possible lack of a proper basis for analyzing the situation, I made a personal reconnoissance of several rivers where the concentration of industries or particular kinds of manufacturing had contributed large quantities of waste to the streams on which the establishments were located. In this way I saw the effect produced upon stream waters by wastes from steel plants, from tanneries in different places, from glue plants, from various sorts of paper mills, including those which use the sulphite pulp process, and others. I had opportunity to note the effects of such trade

wastes upon streams of relatively insignificant volume and upon those which rank as the largest in the state.

It does not seem to me to be important that I should report here the details of such examinations. There is little likelihood that the situation at points which were most carefully examined differs in any radical way from that in other places which were not visited. Moreover, no effort was made at any point to study the situation intensively so that one could speak with exactitude regarding the amount or precise character of the pollution. I endeavored to get a broad and yet clear conception of the general situation from the point of view of the biologist. I hope to make clear in later paragraphs the general appearance presented and the inferences which may reasonably be drawn even from what might seem like a superficial examination of the situation.

Only a small number of streams was examined, with a view to determining the general conditions existing in them at the particular time; certain preliminary statements with reference to the method followed should be made before an account is given of the results of the examinations.

In the first place, while no attempt was made to determine the *detailed* conditions at the time of the survey, yet the waters were examined carefully up and down stream from the point where the wastes were discharged, and the *general character* of the shore and bottom and of the open water was determined in so far as it could be by mere examination. Wherever plant growth was seen or any sort of animal life was noticed careful attention was paid to the amount and character of the same, the extent of its distribution and the vigor of its growth. The natural aspect of situations of the type under examination was constantly kept in mind and was compared with the situation actually existing in order to determine the particulars in which there was an agreement and those in which the present conditions differed from what might have been expected.

It will thus be seen that the examination was general and conducted from the biological standpoint. No effort whatever was made to determine more precisely the conditions of existence by chemical examination of the water or of the wastes, by any measurement in the flow of the stream or of the amount of wastes discharged, or by the study of the materials deposited on the bottom or of those observed floating in the water. Such studies would be of great value and should be a part of any extended and continuous survey of conditions in the state. At the same time it was possible

to determine the general aspect of the stream, and to decide whether conditions were favorable for the existence of aquatic organisms, or if not, in a rough way to what extent they were unfavorable. It is of course easy in the extreme case to recognize such conditions as destroy all organisms except those that live in polluted waters. Thus, while the survey was confessedly superficial, it was sufficiently accurate to determine the general situation and for the purposes of this investigation such a determination was adequate.

In the next place, attention should be called to the fact that at the time when these examinations were made, conditions were not far from the average. Frequently one finds during the summer months, when alone I was at work on this problem, such a reduction in the amount of water flowing in the streams that the effects of materials discharged into it are relatively very much greater than usual. The strikingly bad situation in the streams of New York state during periods of summer drought have been commented upon so widely and recorded by so many kinds of observers that in their general features they are probably familiar to all. At the time, however, when I was on these streams, the water supply was larger than usual in the summer and consequently the statement of results must be looked upon as portraying not extreme conditions but those which are at least as good as would be found on the average.

Again it should be noted in connection with these examinations that no effort was made to determine the presence of fish, either adult or young. Whenever it happened that fish were observed, a record of the fact was made, but proper catching apparatus would certainly have demonstrated the presence of fish in a good many places where they were not seen. In fact, the waters generally examined were those near shore where the depth was insignificant and where one could take in with the eye the general appearance both of the bottom and of the water above it and could see the plants and small organisms in their relative abundance and general relations. Examinations were made of the deeper water also, but these again were confined to such data as could be determined by the eye. No apparatus was used to determine the character of the bottom, in so far as it was invisible to the eye, and no appliances for the collecting of the minute microscopic fauna present in all such waters but giving no evidence of its existence to the unaided eye of the observer. By a more thorough examination numerous additional facts could

have been secured, but it may confidently be asserted that they would not have modified the general picture. They would doubtless have added to the strength of the evidence presented, but on the other hand, no considerable area could have been covered with the time and assistance available.

At the eastern end of Lake Erie a number of short streams with relatively little flow run from a height of land westward or slightly north of west into the lake. They are for the state in general exceedingly important, since in the spring the lake fish resort to them for spawning purposes and upon them depends to some extent at least the supply of the lake fish. I was able to pay a visit to two of these. On one of them, a very small stream known as Rush creek, is located a steel plant. Above the plant the stream is apparently in good condition and favorable for the development of aquatic life. Other conditions were observed some distance below and relatively close to the lake. Here the waters, at the time of the visit, were entirely barren of the ordinary life of such streams, so far as the eye could determine. A deposit and growth on the bottom gave the entire bed of the creek a rusty aspect. Some organisms were present in considerable amounts, but they were those characteristic of waters affording an unnatural chemical environment, and conditions clearly indicated that normal fresh water life had been wiped out. No information was sought or obtained as to the amount or character of wastes introduced or other facts concerned therewith.

Cattaraugus creek is a considerably larger stream having several branches and draining a large area along the southern section of the Erie-Niagara watershed. It was examined at Gowanda, where are located a large tannery and a glue plant. The amount of waste produced is apparently rather large with reference to the flow of the stream and heretofore it seems to have been discharged without any treatment into the waters of the creek. At the time of the visit one could see considerable areas of the bottom of the stream covered with waste material in which lime and organic substances were prominent. The conditions near the plants were extremely unfavorable for the development of the general types of fresh water organisms. In various places were seen patches of those organisms which inhabit highly polluted waters and these conditions extended for some distance down stream. Works for the treatment of the wastes discharged from each of these factories are in process of construction and there is reason to believe that

the character of the discharge will be so modified as to eliminate the undesirable conditions. Pending the completion of these installations no final judgment should be passed on the situation.

A trip was made to Gloversville to examine the results of discharging into the stream there the wastes of a highly concentrated industry. The results of this examination were made the subject of special oral and written reports. Here only general conditions need be stated. The amount of industrial wastes is large and is discharged directly into the city sewage system. An extensive treating plant has been installed to handle the city sewage and should do so well, but becomes clogged because settling tanks at the individual factories are not kept in operation. As a result excessive amounts of solids matted with hair hold up the functioning of the sedimentation tanks at that city plant and a by-pass is opened at intervals to relieve the situation. This transmits untreated materials to the stream, and the situation is further aggravated by the wastes discharged into the creek directly from a few plants not connected to the city system. At the time of the visit the condition of the creek was very bad, as nothing but pollution organisms could live in it anywhere.

On the Susquehanna river which has long been famous for its fishing, is located in New York state only one large city, namely, Binghamton. A short distance down stream are located several large manufacturing interests which have turned their wastes into the river. The conditions below this point have been recognized to be very undesirable and some discussion has arisen as to whether the cause should be attributed to the city sewage discharged into the stream or to the wastes from the industrial plants mentioned. The character of the stream is excellent to enable it to purify itself in the minimum time and with maximum success. It is broad and relatively shallow, thus exposing considerable surface to the air. The flow is rapid and broken by stones and shallow bars over which the water ripples. Multitudes of small currents thoroughly mix the water in different parts of the stream and turn it back and forth from one shore to the other. At the various points where the large sewers of the city empty into the stream the polluting effects are very noticeable and the mixture of sewage and river water can be followed by the eye for some distance. Where this is no longer possible by observation from the shore, because of the changes in the color of the water, it is still easy to determine from a boat that the water carries an abundance of fine

materials characteristic of city sewage, and the bottom deposit shows these to some extent at least in many places. Yet even here one finds considerable amounts of plant and animal life and the situation is much improved before the industrial wastes are added below the city.

These wastes enter in considerable volume at various points and exercise an influence on the stream which is very marked even on casual observation from the bank. The color of the water is modified considerably and deposits on the bottom extend over large areas within which they have a thickness so considerable as to render them conspicuous even from a distance. When one examines the stream from the height of the bridge crossing the river at Endicott, one gets a good general idea of the conditions that prevail. The water has an opaque milky appearance, the bed of the stream is distinctly tinged with deposits, and the patches of green plants are localized, limited in area and not vigorous in growth. Areas are also visible which are over-grown by the organisms that inhabit polluted waters. Even here, however, the wastes are not thoroughly mixed with the stream, and there are regions in which the water is fairly clear and its life, while not abundant, still of the types that belong to unpolluted streams. On studying the water some distance further down stream, a distinct change was apparent. The water was crossed and recrossed in a small boat, thus giving a good opportunity to examine both shores, the small shallow areas and islands in the stream and the general character of the open water and bottom. This study was made on the same day that the stream was examined in similar fashion above Endicott, so that the volume was not modified by weather conditions nor were other factors present to render the comparison invalid or even open to question. The contrast of conditions in the two locations was very great.

Above Endicott one could distinctly see some of the fine floating material that indicated the sewage contamination of the city of Binghamton, but the water was fairly clear and one could see the bottom almost all the way across. There were present plant life and animal organisms of the fresh water types; some small fish and one or two large ones were also observed. The stream was by no means in perfect condition and yet it was not seriously ill. Below Endicott the contrast was marked. The shores were covered with a slimy deposit consisting of decaying organic material and containing organisms characteristic of such an environment. The

bottom was visible only a short distance away from the bank because of the cloudiness of the water, but wherever seen or tested even roughly with a stick it showed the same deposit in considerable thickness. The absence of green plants was extremely noticeable and careful study of several different places did not bring to light any of the pure water organisms, either plant or animal. Large areas were over-grown with bacteria and fungi and little masses of such material rose to the surface and floated away in the current. Where by the force of the stream the bottom had been scoured clear, as on some exposed shallows and projecting portions of the bank, only barren areas could be observed and even there the stones were slimy to the touch from the film of wastes deposited on them. Some fish were seen, but they were all dead and decaying on the bank or stranded in the shallows. While only relatively few such specimens were seen, they had evidently all been killed recently and had not undergone much change since they floated ashore. If, as was maintained by residents, such dead fish are thrown up constantly, then the toll on the fish population of the stream must be pretty large. One could hardly doubt that there had been introduced into the stream in this region a very considerable amount of solid materials as well as more fluid industrial wastes. The effect on the stream had been bad and seems likely to grow worse unless the situation is modified.

It was not possible to study the stream intensively in order to determine how far down these conditions extend or how rapidly, if at all, the water purifies itself and the conditions are ameliorated.

The upper Hudson was made the object of more careful study than was devoted to any other streams or region. Numerous short trips were made along the bank and in small boats from Troy northward. Two more extended surveys were carried out. In the first of these the party proceeded by automobile from Albany to Palmer Falls and examined both the general condition of the stream and the special conditions that existed at those points where the introduction of industrial wastes is most extensive and most marked. As the road runs parallel and close to the river it was generally possible to get a complete picture of the conditions and to note changes in appearance as well as to stop readily for an intimate examination wherever a change was evident or was suspected.

With the stretch from Troy to the site of the present Waterford dam, I was very familiar as a boy some thirty to forty years ago

and while I realize the danger in attempting to comment on such conditions from memory when the interval of time is so large and the opportunities for influencing one's recollection of conditions are so numerous, yet I am confident that after all allowance has been made it is possible and just to say that the situation has been very greatly modified and that such a modification represents a distinct deterioration of the stream.

A careful study of the upper Hudson and its tributaries was made for the state of New York some years ago with special reference to the question of pollution.* Records are given in it of the turbidity of the water and other characteristic features in its appearance. What was said concerning the river at that date is even more strikingly true at the present time. To these observations may be added some comments on the biological situation. In the stretch from the state dam at Troy to the Waterford dam the water is very dark in color and does not carry in any conspicuous fashion floating masses of scum or material released from the bottom. However, there is scanty evidence of plant growth or of the organisms that ordinarily inhabit such waters and that previously could be collected in great abundance more especially at the so-called riffs where the water was somewhat broken in its rapid progress over rocky or stony bottoms.

The most conspicuous industries of the upper Hudson are the paper and pulp mills. The character of their wastes is well known and has been the subject of numerous special studies. The most extensive of these was published by the United States Geological Survey in 1909.† At present the situation does not differ greatly from that described previously, although works recently constructed by the state of New York have modified conditions radically in certain respects which are significant in their bearing on the biological aspect of the situation.

Effects of Canalization

The region has been transformed by a series of dams into what is substantially a canal. The water backs up from each dam almost to the foot of the one next above it and the intervening area of the stream is a huge basin of quiet water. The general effect of such conditions is discussed from the biological stand-

* 1908 Report on the pollution of the Upper Hudson by industrial wastes — Annual Rept. State Dept. Health, N. Y. 28:407.

† Phelps, E. B. 1909. The Pollution of Streams by Sulphite Pulp Waste. U. S. Geol. Survey, Water Supply Paper, no. 226; 37 pp, 1 plate.

point in another section of this report. Conditions on the Hudson were typical in this respect. The recent date at which most of these dams were completed and canal conditions produced is evident as one examines the stream. Just below each dam or about at the point where the river gets a new load of trade wastes discharged into it conditions are very bad. The water is altered in appearance, its turbidity greatly increased, and the bottom covered over with a slimy deposit on which are growing the organisms that characterize highly polluted streams. One can trace step by step the development of these conditions as the waste pours out from the discharge pipe and mixes with the current, spreading gradually more and more widely towards the opposite bank of the stream, producing thus a fan-shaped area within which, as accords naturally with the higher concentration there of the waste materials, the modification of natural stream conditions is most marked. After the discharges have been thoroughly mixed with the waters of the stream, one notes a uniformity in the appearance of bottom and open water for a greater or less distance down stream, depending upon the amount of waste which has entered and the date at which such discharges were first introduced into the river. Thus at the oldest mills the modification was most striking and extended farthest down stream. At the manufacturing plants of more recent construction the extent to which one could trace the modification down the river was distinctly less, and in some cases only a beg nning had been made of the process of destroying the normal life of the water.

In most cases normal conditions appeared, although very gradually indeed, as one approached the dam next lower down. Conditions were best a slight distance above this dam, for the reason that at the dam the mechanical interferences with conditions incident to its construction had been greatest and changes in depth, together with the removal of shore material or the deposit of construction refuse, had made very radical changes in the original condition of the stream. On passing up stream one noted that in many cases just a short distance above the dam, where the conditions of the original stream had not been interfered with at all, except by raising the water level, the plant and animal organisms of the water appeared to be fairly characteristic of unpolluted streams and sometimes manifested a completely normal aspect. On the whole, however, it must be said that the number of such organisms was less than normal and the vigor of their growth was impaired,

so that even here it would be necessary to pronounce the stream ailing if not actually sick. As our survey proceeded up stream, conditions grew slowly and very gradually worse until they reached their maximum near the entrance of a new supply of polluted materials, somewhere toward the foot of the dam next above. Where dams were close together, conditions seemed to be bad throughout the entire stretch, but where a long interval intervened between two dams, the river had evidently had time to recover, or the period since the construction of this portion of the canalized stream had not been long enough to allow the wastes to spread far down stream, and a considerable area of reasonably normal water was observed.

Some of the side streams stood in interesting contrast with the main river. Thus at Schuylerville there was observed a considerable portion of the stream where conditions looked very much better than those in the region generally. This was just off the mouth of the Batten Kill. On making a study of this stream as far up as the first mill, it appeared that the stream flow was relatively large, the pollution at this point not great, and the effects on life in the water evidently slight. Conditions were said to be different further up, but we did not have opportunity to investigate this stream more particularly.

At Fort Edward, Hudson Falls, and Glens Falls one finds a considerable number of large mills within a relatively short distance. The amount of wastes discharged into the stream was very large and its character evidently exceedingly unfavorable to the existence and development of aquatic life. From the care with which this waste product of one large establishment is conveyed in pipes some distance down stream and turned out onto the rocks below the wheel pits, one might infer that the material discharged was strong enough to have an unfavorable effect even on the machinery. Certainly no one could doubt for a moment that it had been in the highest degree destructive to the organisms that naturally are found in the river water. The wastes discharged into the stream in this region are so extensive in amount and powerful in character that one is not surprised to find the water through this stretch of the river apparently devoid of any life whatever. Below Fort Edward the stream is more highly polluted than at any other point in the area studied, if one may judge from the biological conditions. For some distance there is complete absence of normal fresh water organisms and for a long stretch one finds only scanty traces of the pure water fauna and flora.

Even a superficial examination of conditions showed very clearly that different establishments varied widely in their methods of handling these waste materials. In some cases they were discharged without any treatment whatever, in other cases certain materials were extracted, and in still others more complete treatment was given to remove the waste products.

I am not able to find that any experimental information is available concerning the effect on aquatic organisms of such partial or complete treatment of these wastes. It is evident that this is a very important problem from the standpoint of the Conservation Commission. One has no right to infer that the removal of certain substances from the industrial wastes will make the residue any more favorable to the preservation of the aquatic life and for the development of aquatic organisms in the stream after the waste has been added to it. Indeed, one may go further and say that even concerning certain processes for the complete treatment of such wastes there is no information as to the effect such treatment has upon the influence the waste exerts upon the living things in the water of the stream. From the standpoint of conservation, it is extremely important to determine precisely how such changes as are now practiced, and those which may be advocated for the future treatment of wastes, will affect the plant and animal organisms in the water. It is evident that the stream may be as seriously damaged by its conversion into a lifeless desert as by adding to it those wastes which make of it a septic tank. In my opinion, this is one of the first problems which the Commission should plan to attack and for its solution it will be necessary to engage the services of a man trained in experimental biology and familiar with chemistry, while of course, he should be primarily a student of the natural history or ecological phase of aquatic biology.

At Palmer Falls is located the first of the sulphite mills on the upper Hudson. A general examination of the stream above this point shows that it has the aspect of a reasonably pure and natural water course. The river banks below the mill from which there passes into the stream a large amount of sulphite pulp wastes disclose a rich and extensive growth of very flocculent material on the rocks. This covers all available area, extending well above the present water line to high water level or towards that point. The portion of this material on the stones which at the time of the visit were above the water level, had been dried out and appeared

like a thin coarse blotting or wrapping paper. It would naturally lead the observer generally to the conclusion that waste paper pulp had been deposited on the stones and after the falling of the water had dried there. Examination of the material in the water showed, however, that it was of a very different character from pulp fibres. The rocks were overgrown with soft gelatinous, branching, filamentous masses, rather loose and yet sufficiently firmly attached to the rocks to hold in place even where the current moved strongly. Pieces of this material torn free were constantly floating down stream and accumulated in the eddies lower down or floated on the surface as flocculent masses. Careful inspection of the material in place will convince any one that it is not an actual deposit of fibres, but a growth which has both structure and continuity. Furthermore, it is somewhat filamentous in texture, as may be readily ascertained, and does not partake of the nature of wood fibre. It is a fungoid bacterium and clearly indicates the highly polluted condition of the water which, with its addition of sulphite liquor at this point, gave precisely the environment most suited for the development of this particular class of organisms.

No better illustration could be given of the fact that the addition of this industrial waste has powerfully modified the normal conditions of the stream. This material grows only under these extreme and abnormal conditions of environment and the very existence of those conditions is fatal to the development of the aquatic organisms that frequent pure waters. Such organisms are indeed the best index of polluted areas and until the conditions have been modified so that they cannot exist, it is hopeless to expect that the normal fauna and flora can be restored. The conditions described extend some distance down stream. They were not followed continuously, but on a subsequent trip similar organisms were observed, though less abundant, in the water above the Spier Falls dam, so that one may infer their probable presence throughout the intervening stretch of the river, especially since in this stretch the water is quiet and has relatively little opportunity to purify itself.

At a later date the water of the Hudson through much the same region was studied from a boat. The party went up stream on the Conservation Commission boat as far as Fort Edward. The general character of the stream and the special conditions in the channel were observed throughout the entire stretch. From point to point the shores, backwaters, and shallow stretches along the

banks were studied from a rowboat and wherever it appeared that conditions were modified by the addition of waters from tributaries or of discharges from industrial plants a more special examination was made of the particular region involved. The facts gathered did not differ materially from those observed on the first trip already described. They furnished more abundant evidence, however, of the conditions already noted and strengthened the argument materially. It was possible in the various cases to follow more exactly the transformation from highly polluted water, at the points where the large discharges of industrial wastes into the river made the stream largely if not entirely a polluted water course, lacking the natural aquatic life, to the regions lower down, where that natural life was more or less perfectly restored. Perhaps it would be in more precise accord with the natural conditions to say that at these points further removed from the sources of contamination the original life of the stream had been only slightly impaired and that as one moved up stream towards the source of the pollution the life was more and more adversely affected by the condition of the water until it finally disappeared entirely.

At the points near the mills water conditions were the worst. One found floating great pads of thick scum in which were enclosed numerous gas bubbles, and it was easy to demonstrate that such masses had been torn loose from the bottom by accumulated gas and had floated up to the top. All stages were observed in the formation of this thick bottom scum and in the accumulation of the gas that was in it, but these phenomena are well known and have been carefully described in the report on the pollution of the upper Hudson to which reference has already been made. It may not be out of place, however, to emphasize again the fact that wherever this bottom material had accumulated the life characteristic of pure waters was entirely absent, save that once or twice we did observe a solitary fish moving into or across some of these regions. In these places the amount of such material accumulated was moderate and no life whatever was observed in those places where we observed the most extensive accumulations of this deposit.

Leaving the boat at Fort Edward the party proceeded by trolley and conveyance to Big Bay, which is a familiar fishing ground in a large bend of the river several miles above Glens Falls. From this point up stream to the Spier Falls dam I made a most careful study of the water in a rowboat and on foot along the shore in

company with Game Protector Teal. In Big Bay itself the stream is in splendid condition. The profuse growth of aquatic vegetation gives hiding places for the fish, nourishes an abundant population of small aquatic organisms, and affords them every opportunity for reproduction, so that it is natural to find an aquatic fauna varied in character of species and rich in number of individuals. As is well known, this region is one of the very best fishing grounds that the Hudson affords and, as long as natural conditions are preserved and the amount of fishing is not permitted to surpass reasonable limits, may be relied upon to furnish enjoyment for a large number of citizens.

The shores of Big Bay are clean and the stones entirely free from the slimy deposit which even in some fairly good portions of the river farther down stream can still be detected on careful examination. The plants show that bright, fresh, green color which indicates their perfect condition, and careful search failed to disclose any of the organisms of polluted water. Just above Big Bay are some conspicuous riffs where the stream ripples down over stony and rocky stretches. For several miles up stream areas of still water and of ripples alternate, until one reaches the foot of the Spier Falls dam. Even in the still water stretches the stream is broad and shallow, the water well exposed to the light and air and well mixed by the conflicting currents which are produced by the curves of the stream and the presence in its course of bars, shallow stretches and series of larger stones and boulders. The stream was studied with a boat as long as it was feasible to make progress in that fashion. Thereafter it was examined from the shore and at frequent intervals up to and above the Spier Falls dam. Just at the foot of the last stretch of rapids, before the stream entered a short sweep of still water that opened out into Big Bay, I found the first evidences of pollution in the form of some small pieces of floating scum and scanty growths of the pollution organisms, as well as an insignificant trace of slime on the stones in a few places. Furthermore the plants that were present here showed sometimes a paler coloring and less robust and vigorous growth than those in the Big Bay region. It would be unjustifiable to maintain that these were positive evidences of pollution, and if the facts just mentioned had been the only evidences secured, one would have passed them by with the suggestion that the richness of the aquatic vegetation is subject to fluctuations and that this was merely a less favorable point for the development of such

forms than one found lower down in the stream. But these conditions formed in fact the last link of a chain that could be traced up stream without a break to the pool at the foot of the Spier Falls dam. The difference from moment to moment as we proceeded along the bank was too small to be measured in territory that was contiguous, but these differences grew by imperceptible gradations until from the conditions just described at the one extreme, one reached the other extreme, which was conspicuously noticeable in the water below the dam at Spier Falls. Whereas the evidences of pollution were so extremely scanty as to be almost unnoticeable at the lower end of the territory, they spread over the entire stream at the upper end and were, moreover, conspicuous in some portions of it. In the stretch of the river just below the dam one could find a considerable growth of the organisms that have already been noted as characteristic of waters polluted with sulphite wastes. The entire stream was not affected in this way and one could see areas that were only slightly involved or apparently entirely free from such growth. Along the bank, however, where we could observe most perfectly, it was possible to find these organisms at almost every point. There was also a noticeable lack of the normal pure water organisms. One can readily represent to himself the changes which were taking place in the stretch of the river below this, where its waters were exposed to the air and sunlight and undergoing rapid purification. The process was aided by the character of the bottom, which brought about a mixing of surface and deeper waters and of the waters from different parts of the stream. It was, of course, greatly aided by the ripples, in which the water added conspicuously to its oxygen content, and the result was that by the time the stretch had been covered, pretty nearly all of the effects of pollution had disappeared.

Passing around the dam, I studied the deep water above, in so far as it could be observed from the shore. In color, turbidity, presence of floating flocculent matter, in the growth of pollution organisms in shallow places, and in absence of the organisms which characterize pure water it had all the appearances of a stream polluted by sulphite waste liquids, and recalled precisely the conditions which had been observed in the vicinity of Palmer Falls on the previous trip. There certainly were few, if any, pure water organisms living in it, and we did not see any evidence of fish whatever. From men living and working along the stream I learned that there were no fish above the dam, as, according to the testimony given, they

had all been killed off by the polluted water, and that occasionally dead fish were washed ashore at various points, which might fairly be taken to indicate the effect of the waters upon such fish as chanced to migrate into them from purer waters above.

At the time of our visit no water was going over the dam and the stream below was made up exclusively of that which had gone through the gates of the power plant. In making the passage of the wheels the water was so thoroughly churned up that the floating masses were not recognizable below, or at the most were demonstrated only by the presence of fine flocculent matter which could be distinguished in the pools formed after the water emerged from the plant. The condition below the dam was not as bad as that above. The reasons for this, however, were evident in the fact that the stream was shallow, more exposed to air and sunlight, and was flowing more rapidly, as well as being broken in flow by the character of the bottom over which it passed. All these things would tend to restore the water to a natural condition and to favor the introduction of pure water organisms as well as the destruction of the organisms of pollution.

It appears from reports of the engineers that a new dam is projected which will be located just above the head of Big Bay. The stakes indicating the preliminary survey for this plant were found in our walks along shore and gave a reasonably accurate idea of the location which this dam will have. I should be remiss if I did not point out very distinctly here the probable results of installing such a project. The dam as constructed will impound water that will assume a level near that of the base of the dam at Spier Falls. The stretch of the river between the Spier Falls dam and Big Bay, which is now a shallow region of fairly rapid flow and broken surface, with successive stretches in which the water is thoroughly stirred up and mixed with the air, will be transformed by the building of the dam into a deep, quiet stretch that will approximate very closely the conditions of a canal. This repeats exactly the conditions that obtain above the Spier Falls dam, and the result will be to replace the present stream conditions biologically by those which are found above the dam at Spier Falls. The stream will not purify itself to any extent and the polluted areas which have established themselves at the base of the Spier Falls dam will spread slowly down stream until they involve the entire basin. Even before this has taken place, the water which discharges itself from a new dam will be very much like that which is now discharged from

the Spier Falls plant. This water will pass directly into Big Bay without any opportunity to purify itself.

One cannot tell how rapidly the changes will take place for they depend upon a large number of factors which cannot be stated in exact terms or estimated from the evidence in hand with any degree of accuracy but it is clear that sooner or later, with a speed which will depend upon these undetermined conditions, but with a certainty which is not open to question, the waters of Big Bay will be contaminated until they no longer afford favorable opportunities for the development of the rich natural flora and fauna that now exists there. As this aquatic life begins to disappear the fish will be subject to two general influences of a very unfavorable character. First, their food supply will be restricted, and with that restriction their own growth and other activities will be reduced. This will show its effect most distinctly on young fish, for not only will they face starvation, but, because of the loss of shelter which the plants now afford them, they will be more subject to capture and destruction. The smaller kinds of fish, upon which the larger depend, will disappear most quickly, but the effect will be evident soon all along the line. In the second place, the opportunities for reproduction will be interfered with most seriously. A layer of polluted material on the bottom renders conditions unfavorable for the development of the eggs.

It is probable also that the varieties of small fish which constitute food for the larger fish go above the Big Bay region into the riffs, seeking opportunities to spawn, and with the removal of these areas they will find only imperfect facilities for carrying out the reproductive function. This loss may be inseparably connected with the adequate utilization of the stream for industrial purposes, and if so, must be faced as one of the features in natural conditions that must be sacrified in order to allow the profitable utilization of natural resources by the human race. It thus differs distinctly from other difficulties that have been mentioned, for they are the product not of the change in the stream by the erection of the dam, but rather of the modifications in the stream induced by discharge into it of the waste products from the mills. The manufacturer has neither legal nor moral right to turn these waste products into the streams when they affect adversely the fish life of the waters either in its adult condition or in the discharge of its reproductive function. In any event, if a new engineering project is to be installed, it is, I believe, the duty of the Conservation Commission and of the other

legally constituted authorities of the state to consider fully and carefully the consequences of such installation and to guard to the utmost against results which will prejudice the welfare of the people in general or destroy natural conditions that are a source of present advantage to the state. There is no doubt whatever that the erection of a new dam at the point indicated and the canalization of the stretch from this place to the Spier Falls dam will have a serious and perhaps permanently unfavorable influence on the famous fishing region at Big Bay.

This preliminary survey covered only a small part of the water systems in New York state, but the territory examined was such as to give a fair idea of general conditions. The regions described are neither those in which stream pollution is most extreme and conspicuous nor those in which the influence of pollution is least marked. Furthermore in those places which are described I have given only a general report of conditions; more careful study would certainly bring out more vividly the results of pollution on aquatic life. Yet brief and in a sense superficial as the survey was, it brought out clearly the widespread and serious effects already produced by stream pollution. I have tried to show how these influences are growing, how difficult it is to repair damage done, and how real is the menace to regions as yet unaffected. From every point of view the question demands early consideration and above all else prompt action to repair the damage and prevent further loss. The public interests should be safeguarded by vigorous measures. Otherwise New York state will suffer still greater losses and be compelled to assume larger burdens for the restoration of her aquatic resources to a normal level.

RECOMMENDATIONS

Census of Cases of Pollution

The examination of the field and the study of the question of pollution, with especial reference to New York State, during the past summer has thrown some light on the proper means for solving the problem of stream pollution and on preliminary work which must be done before the specific methods can be generally applied. Evidence enough has been secured to show the seriousness of stream pollution at the present time within the limits of the state, as well as the rapid increase in the immediate past and the still more serious outlook for the future. It is, however, necessary to confess that no one knows the extent of stream pollution in the state and the character of the different wastes which are coming from the varied manufacturing plants within its limits. Consequently, the first thing that should be done is to organize means for taking a census of individual cases in the state in order to determine the location of these and their relation to the different streams and watersheds, as well as the amount and character of the wastes produced, fluctuations of the same with the seasons or other periods of time, and the exact extent to which the life of the water has already suffered by the discharge at individual points. The situation is certainly critical in some places, and even a lenient enforcement of the present laws would eliminate some difficulties, but we are still unfamiliar with the exact extent of the problem. After this census, it will be easier to say how to proceed in the enforcement of the conservation law for the entire commonwealth.

Need of Continued Study

In the next place the character of the wastes produced and their effect upon aquatic life is only partially understood. It was the unanimous opinion of the game-protectors, as expressed in the reply to a specific question on this point, that not anyone of the industrial wastes was in any respect advantageous to the fish life of the stream. On the other hand, it is certainly true that, as indicated above, the different chemicals exert a varying influence on the aquatic fauna and flora. For evident reasons it is important that the precise effect of individual substances should be determined. In some cases it will be possible to secure data on this from the literature on the

subject. The records of investigators elsewhere have many of them been published, and in so far are available for the authorities of New York State in their consideration of the question as to violations of the terms of the state conservation law as it now stands. After all these have been determined, however, there will certainly be many points left on which no information of a definite character can be secured. The Conservation Commission should provide for a special investigator who has been trained in aquatic biology and who is also well informed in the chemical field. Such a biologist should devote special attention to the study of the effects produced by different kinds of wastes, that he may advise properly and wisely concerning the steps which should be taken to correct the evils that exist. It is, in my opinion, important that this man should be expertly trained in the study of aquatic life, that he may be of maximum assistance in the work which most urgently demands the attention of the Conservation Commission in this subject.

Reclamation of Wastes

There is another phase of the general problem that will undoubtedly yield profitable results, if thoroughly investigated. This is the question of the possible reclamation of wastes now discharged from different industrial plants. The ultimate solution of this question demands, to be sure, high technical knowledge in connection with each individual industry. It is primarily the work of the special chemist associated with the industrial plant producing the waste, and he should be brought to handle it promptly, as evidently only he can handle it most effectively. On the other hand, it is evident that the Conservation Commission may by general investigations add to the knowledge in this field. In so far as the problem concerns individual industries, the Commission may effectively serve as a clearing house for the transmission of information gained at one point to similar manufacturing plants in other parts of the state. It evidently should keep itself and the manufacturing interests of the state informed with reference to the effects of classes of industrial wastes on aquatic life and the possibility of utilizing certain by-products, the removal of which will so modify the wastes as to make them relatively or entirely innocuous. In the ultimate analysis, of course, the reclamation or utilization of industrial wastes is a problem that belongs to the specific industry, and that cannot be adequately or effectively handled except by chemists and others trained in the specific conditions of that industry. The handling

of such trade wastes is furthermore an evident responsibility of the business involved. It is not too much to ask that the business should assume this responsibility in the same way that it does other obligations involved in the transaction of its business affairs, even though the assumption makes it liable to expense. The partial reclamation of industrial wastes is often profitable and occasionally highly so. But the partial utilization cannot be looked upon as an advantage to the public until it has been demonstrated that the residue is less poisonous to animal life or in some other way less significant as an element of danger in the water system into which it is discharged than the total industrial waste which it displaces.

Education of Public Opinion

In order to secure adequate support for the proper enforcement of any conservation law dealing with stream pollution, it will, in my opinion, be necessary to educate public opinion on the significance of the present situation. It is not too much to maintain that the average citizen fails to comprehend the value to him and his fellow citizens of the natural waterways. Of course, one would expect that those engaged in manufacturing and personally interested in the problem of disposing of waste matter in the easiest and most inexpensive manner would be likely under any conditions to take advantage of an easy opportunity which presented itself for removing this material from the immediate vicinity of their own activity; but manufacturing concerns have not really been the leaders in adopting such a method for the disposal of waste. In the average mind a stream is regarded as a convenient and natural means of getting rid of waste matter, whatever its source or character; anything thrown into the water is carried away, and the locality is thereby relieved of the burden of accumulating wastes; the objects are removed from sight and smell and the mind easily relieved of any sense of obligation for the materials which have accumulated in the course of various activities. In this way the average citizen began what the manufacturer has continued on a larger scale.

How deeply fixed in the average mind such a habit is may be illustrated by occurrences which have come under the observation of all and which I have indeed myself witnessed. Wagons loaded with refuse taken from streets and alleys are dumped on low lying lands, where a slight rise in the water level carries them into the stream, or even are thrown from the banks of the stream into the current itself. Now if this is not commonly practised at the present

day by municipal authorities, because of the interference from state officials concerned in safeguarding the conditions of the streams, it nevertheless can frequently be witnessed on a small scale in many places, and is a regular habit on the part of citizens whose establishments border on water courses, especially where the amount of refuse is small and the practice of throwing it into the stream is not accompanied by such conspicuous evidence of the occurrence that comment and official criticism is provoked.

This is really a survival of the ancient method of disposing of garbage and waste in cities and towns at large. What was not wanted by the property holder was carelessly pitched over the wall into the public roadway, and while perhaps few men of the present generation can recall accumulations of rubbish in the front streets of American cities, they were frequent in the recent past, and are still to be found at times in the alleys and on the vacant lots of some cities. The practice, so far as it concerns public roadways, has been thoroughly discountenanced, and generally is specifically prohibited by law that is well enforced at the present date; but the waterways, which have inherited the practice, have not yet been adequately protected against this evident violation of general community interests. The reasons are not far to seek. As piles of refuse on the streets are conspicuous and often offensive to the citizens of the immediate locality in which they are produced, the source is readily determined for the most part and the responsibility easily placed. Where waste matter is emptied into the water highway, liquid material is diluted, and larger, more solid wastes rapidly broken up, until their character is not readily ascertained; moreover, the source is in many cases so distant that, while it might be determined, the responsibility for the condition is not distinctly placed without much expenditure of time and energy.

It is time to clear our minds of the conception that a water roadway is an appropriate receptacle for waste material, any more than the streets of our cities. Indeed, it may confidently be said that the habit of using the streams for the reception of waste results in more unsightly conditions than follow the accumulation of ashes and rubbish in piles along the highway, and the ultimate consequences of adding wastes to the streams are more serious for human existence than the practice of permitting garbage to decay along the roadside.

To what an extent advantage has been taken of the general state of public opinion and the laxity of public officials, or the want of

legal restrictions for proper control of our streams, may be judged by the fact that boats plying upon river and lake waters have been frequently seen to indulge in the practice of throwing over-board sweepings, rubbish, broken packing-cases, garbage, and other waste materials. The practice has become in some rivers so general that one may regularly find upon the bank at certain points broken boxes, spoiled fruit and other remnants from the kitchen department of river boats These things are not only an offense against general decency, but render the river unsightly and constitute a damage to which property owners justly object, and in which their objections should be reasonably supported by the community at large. The damage wrought in this way may on the whole be small, but it is conspicuous and it is also certainly conducive to the formation of a false public sentiment, so that it should be not only discouraged but stringently forbidden. Definite action in such cases, and the discussion of the situation in the public press, will do much to formulate the right public opinion and pave the way for a broader conception of public rights and for the support of public officials in protecting those rights. I would, therefore, recommend that steps be taken to introduce and enforce appropriate legislation. This should make it a misdemeanor: 1. for persons, corporations, or municipalities to throw rubbish, animals dead or alive, waste paper, boxes, etc., into any lake or stream; 2. for any boat to dump garbage, sweepings, waste or rubbish of any sort into a lake or river.

Necessary to Enlist All Influences

Finally, it seems to me that the Conservation Commission should organize an educational campaign and acquaint the citizens of the state far and wide with the value of their aquatic resources, the dangers that are faced by virtue of the increasing pollution of streams, and the means that should be taken to eliminate these troubles. It is imperative not only to restore the streams to their primitive condition and to make them again as beautiful and useful as in the past, but, also, to develop the aquatic resources so that they shall be a source of greater pleasure and profit to the individual citizen and to the state. In this educational campaign, every effort should be made to enlist all possible agencies in the work. The regular educational forces of the state should be called upon to contribute their share to the movement. There is now conducted at various times in the educational program of all schools and colleges considerable work on natural history, on the resources of the state, and on its plants and animals. The attention of teachers should be called to the importance of indicating at the proper points

the significance of changes that are taking place; they should be taught to appreciate and in turn to make their scholars understand the difference between those changes which are essential results of increasing population and of subjecting the earth to the profitable uses of mankind and such as are due to the carelessness or greed of individual citizens or limited groups. Especial attention should be paid to the organization of this work in the school system, so that it may be as widely and effectively introduced as possible. The effect of such propaganda cannot be overestimated. After a few years' work the number of persons thus trained to appreciate the significance of our aquatic resources will be great enough to constitute an irresistible force in favor of right legislation and of proper enforcement of existing laws. The study of bird life in our schools has done much to protect the birds and influence proper legislation as well as to make men appreciate the value and beauty of these members of our fauna. The same sort of work with aquatic animals will give irresistible support to conservation measures affecting the aquatic organisms.

State extension work, influences of libraries of all kinds, and all scientific organizations, like the local game protection associations and such general bodies as the Agassiz Association among school children, should be actively enlisted in behalf of this work, which will appeal to them and which will be greatly advantaged by their assistance. Of course, as forestry workers and associations are directly interested in this problem, they should be utilized to spread information of the proper type. The influence of public lectures and moving-pictures should not be forgotten. If the Commission were to prepare and have shown throughout the state, with appropriate comment, a film illustrating the value of our aquatic resources and showing infringement on them at various points, many would be brought to think of the problem and to lend their influence for its proper solution who would not otherwise come in contact with the question at all.

National Vigor and Food Supply

I cannot close this report without calling attention again and in emphatic manner to the far-reaching importance of the question of stream pollution. We became aware during war times of the significance of food and the seriousness of all influences which reduce its quality and quantity, as well as the great importance of measures for increasing the sources of the food supply. It must not be forgotten that the question is more than a problem of war times. It

seems likely that food will never again be as cheap in this country as it has been in the past. The American nation has enjoyed a varied food supply obtainable in abundance at reasonably low cost, and there is little doubt that this has contributed to produce the physical vigor and intellectual strength and the independence of action of which we as a nation are proud. If this is in any degree true, it becomes the paramount duty of those responsible for the conservation and development of national or state resources to exert every possible influence for the protection and increase of the food supply; to resist procedures that threaten any limitation of it, and to improve the conditions that surround its production. Stream pollution threatens the existence of aquatic life. It has already contributed to the reduction in our production of fish food, and if continued will ultimately destroy this great national resource. No one would for a moment think of permitting the destruction of great areas of fertile land. The total area of our water bodies represents a very large fraction of the usable surface of the dry land. The changes which have been going on under the surface of the water have failed to impress us because they have been hidden from view. We have, however, means of testing these changes definitely and of applying means for the correction of the evils. It is incumbent upon us to ascertain the exact facts and to act before our splendid aquatic resources have been entirely destroyed.

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